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Methods for evaluating work-related musculoskeletal neck and upper-extremity disorders in epidemiological studies

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List of papers

This thesis is based on the following papers, which will be referred to by their Roman numerals.

I Toomingas A, Hagberg M, Jorulf L, Nilsson T, Burström L, Kihlberg S. Outcome of the abduction external rotation test among manual and office workers. *Am J Ind Med* 1991; 19:215-27.

II Toomingas A, Nilsson T, Hagberg M, Lundström R. Prospective aspects of the abduction external rotation test among male industrial and office workers. *Submitted*

III Toomingas A, Németh G, Alfredsson L, Stockholm MUSIC I Study Group. Self-administered examination versus conventional medical examination of the musculoskeletal system in the neck, shoulders and upper limbs. *J Clin Epidemiol* 1995; 48:1473-83.

IV Toomingas A, Theorell T, Michélsen H, Nordemar R, Stockholm MUSIC I Study Group. Associations between self-rated psychosocial work conditions and musculoskeletal symptoms and signs. *Scand J Work Environ Health* 1997;23:130-9.

V Toomingas A. Characteristics of pain drawings in the neck-shoulder region among working population. *Submitted*.

VI Toomingas A, Alfredsson L, Kilbom Å. Possible bias from rating behavior when subjects rate both exposure and outcome. *Scand J Work Environ Health* 1997;23:370-7.

Abbreviations used in this thesis

AER test	abduction external rotation test
CIR	cumulated incidence ratio
CR10 scale	category ratio 10 scale
CV	coefficient of variation
κ	kappa coefficient
MSD	musculoskeletal disorders
PPV	positive predictive value
PPT	pressure pain threshold
PR	prevalence ratio
r	correlation coefficient
ROC	receiver operating curve
ROM	range of movement
RPE	rated perceived exertion
TOS	thoracic outlet syndrome
VAS	visual analogue scale
WRMSD	work-related musculoskeletal disorders
2-PD test	two-point discrimination test
95%ci	95% confidence interval

Contents

1. Introduction

1.1 The scope of this thesis and the structure of this introductory chapter

This thesis applies primarily to epidemiological studies of work-related musculoskeletal disorders (WRMSD) in the neck and upper extremities. Much applies however also to epidemiological studies of non-work related disorders, to health surveillance and to studies of other regions of the body.

The methods studied in this thesis are mainly those assessing the disorder state by gaining information from individual subjects. Registers or sources of aggregated health information are not studied in this thesis, nor are disorders primarily due to accidents, systemic diseases, cancer or other tumours.

The over all structure of this introductory chapter is described below, also indicating the specific relevance of the sections for the different studies I-VI in this thesis.

Section	
1.2-3	-the relevance of the topics of this thesis
1.4	-some aspects of terminology and definitions
1.5	-an over all model of relations between exposure, disorders and other effects
1.6	-structures that mainly becomes affected; risk factors, pathomechanisms, symptoms, signs and diagnoses, with specific emphasis on the neck/ shoulder muscles and the brachial plexus (Studies I, II, IV and V)
1.7	-the location of these disorders, with specific emphasis on disorders related to psychosocial conditions (Study IV)
1.8	-quality aspects that are important in assessing disorders, with specific emphasis on rating bias (Study VI)
1.9	-methods in assessments of these disorders; their quality and usability with specific emphasis on self-administered physical examination and pain drawings (Studies III and V).

1.2 Occurrence of the disorders

Musculoskeletal disorders (MSD) have long been a major cause of suffering in many industrialised countries. Besides the low-back region, the neck and upper extremities are the most affected regions. In a nation-wide Swedish survey among working population in 1995 about 28% reported weekly pain in the neck, 27% in the shoulders or arms and 13% in the wrists or hands [194]. About 20-25% of all expenditure for medical care, sick-leave and sickness pensions in the Nordic countries in 1991 was related to conditions of the musculoskeletal system, whereof 20-80% were work-related (re-calculations from [75]). About half of these were located to the neck or upper extremities, accounting for 15% of all sick-leave days and 18% of all sickness pensions in Sweden in 1994 (re-calculations from [193]).

A large part of all reported occupational disorders in the Nordic countries 1990-92 had musculoskeletal diagnoses associated with ergonomic factors - Norway 15%, Denmark and Finland 40% and Sweden 70% [19]. About 2/3 of such reports in Sweden concerned the neck and upper extremities [150]. Similar high proportions of musculoskeletal neck and upper-extremity occupational injuries and disorders are reported e.g. from USA (30% of all nonfatal injuries and disorders) [23]. Knowledge of the prognosis of many of these disorders is limited, but is poor in many cases, in spite of exposure elimination and medical attendance [9, 31]. All these factors taken together have resulted in high costs both for the sufferer, the employers and the community [11]. Rough estimations show that the total expenditure for WRMSD in the neck and upper extremities is about 0.5-2% of the gross national products in the different Nordic countries (re-calculations from [75, 146]).

1.3 More knowledge needed about assessment of disorders

Considerable scientific resources have been allocated to the study of possible causal factors for WRMSD [72]. Still, the knowledge about possible early effects and the progression and persistence of WRMSD is scanty. Mechanisms explaining the relations between stressful psychosocial exposure and WRMSD are also mainly unknown.

Within the science of epidemiology much attention has been paid to the characterisation of critical exposures and the development of valid methods of exposure measurement [68-70, 103, 136, 237-241]. Knowledge is insufficient, however, about what structures and tissues are affected in many WRMSD, and how this could be assessed with reliable, valid and feasible methods. Reliable and valid assessment methods, especially self-administered, suitable for epidemiological studies of the neck and upper extremities should therefore be further elaborated.

1.4 Some aspects on terminology and methodology

"Work-related" in this thesis refers to disorders studied in working populations, in contrast to patient groups, children, elderly or retired people or subjects with systemic and other serious diseases. "Work related" should also be understood as "exposure factors at work and the performance of work are *contributing factors beside many other factors* to the development, to the aggravation or to the persistence of disorders". This is in contrast to "occupational diseases" where there is a direct cause-and-effect relationship between a hazard and the disease, e.g. loud noise and hearing loss [231].

"Disorder" in this thesis means "a derangement or abnormality of function; a morbid physical or mental state" [39]. "Disease" is defined as "any deviation from or interruption of the normal structure or function of any part, organ, or system (or combination thereof) of the body that is manifested by a characteristic set of symptoms and signs …" [39]. "Disorder" is thus a more vague condition, whereas a "disease" mostly has structural changes and observable manifestations [69, 70].

In the science of epidemiology, disorders are studied typically in a general population or occupational or other specific groups. The aim is most often to gain knowledge about the characteristics of the disorder or its relations to different exposures or other conditions in these groups. The methods available for such studies must therefore be suitable for application to many subjects of whom many (most) are healthy. The methods need to be, in addition to reliable and valid, safe, non-threatening, easy and non-expensive to administer and to record. Main methods for assessment of disorders in epidemiological settings are therefore restricted to the use of health registers, self-administered questionnaires and sometimes also personal interviews or medical examinations. This is in contrast to clinical evaluation of single patients or to studies where small patient groups and healthy volunteers are examined. In clinical settings data are assessed using a wide range of more or less invasive methods besides the traditional medical interview and examination. The demands on reliability of the assessment methods are higher in clinical evaluations of single patients. Defects in reliability in epidemiological studies can be handled by averaging data from many subjects in the study group.

Central to all such evaluation or studies is the definition of the disorder or disease. In clinical settings the "diagnosis" is used to define the pathological condition and the affected anatomical structures, e.g. arthrosis of the cervical spine, rupture of the supraspinous tendon. Clinical diagnostics are the result of a mental and iterative process, not governed by simple statistical or formal rules, but more of a pattern-matching process [181]. This process is adapted to each individual patient and it goes on until the diagnosis is reasonably secure. There is an established consensus for the definitions and taxonomy of diagnoses [232].

"Diagnostics" in epidemiological studies based on non-clinical cases, on the other hand, follow pre-determined rules and all subjects are treated similarly. Due to this and the limited sources of information, diagnoses are seldom acquired. Proxies to diagnoses have to suffice. Such proxies could be "symptom diagnoses" based on symptoms alone, or "syndromes"[1] based on combinations of information e.g. on both symptoms and signs. Decision rules and criteria should be defined for these proxies [69, 143, 222]. This is not only necessary for reporting and comparability between studies, but also for the quality of the assessment. It is important to evaluate the usability and validity of these proxies.

The naming of the disorders and diseases should reflect their known character, origin, and location. As the knowledge about many musculoskeletal disorders is vague, many names refer only to the specific symptom and location, e.g. cervicalgia. One such common combination of symptoms and signs in the neck and upper-shoulder region is pain, stiffness and tenderness on palpation (without rizopathia or serious aggravation in movements in the neck). This syndrome has been given many names, "tension neck", "cervicobrachial syndrome", "myofascial syndrome" etc. [109, 220, 222]. In this thesis the name "neck/shoulder pain syndrome" will be used.

1.5 Relations between exposure, disorders and other effects

1.5.1 Model of exposure-effect relations

Risk factors and their possible relations in the development and persistence of WRMSD in the neck and upper extremities can be described as follows (Figure 1). The production of goods or services with the equipment used, the prevailing environmental and social conditions together with the organisation of work, constitutes the individual external exposure. This can roughly be divided into physical/mechanical and psychosocial exposures. This external exposure will not only act as a dose on specific organs and tissues, but also mentally. In this process the external exposure is modified by the individual working technique and coping processes. Working techniques may be characterised by individual choice of order of tasks, speed, forces, movements, etc. (within the limits of the ”freedom” given by the work). Unnecessarily high muscle activity (tension) and lack of muscular pausing when given the possibility could be regarded as aspects of working technique. Depending on the nature of the exposure and on whether it exceeds the individual capacity or vulnerability, this dose can cause early/intermediate, acute or chronic effects.

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[1] "Syndrome – a collection of symptoms and signs which tend to occur together and form a characteristic pattern but which may not necessarily be always due to the same pathologic cause" [219].

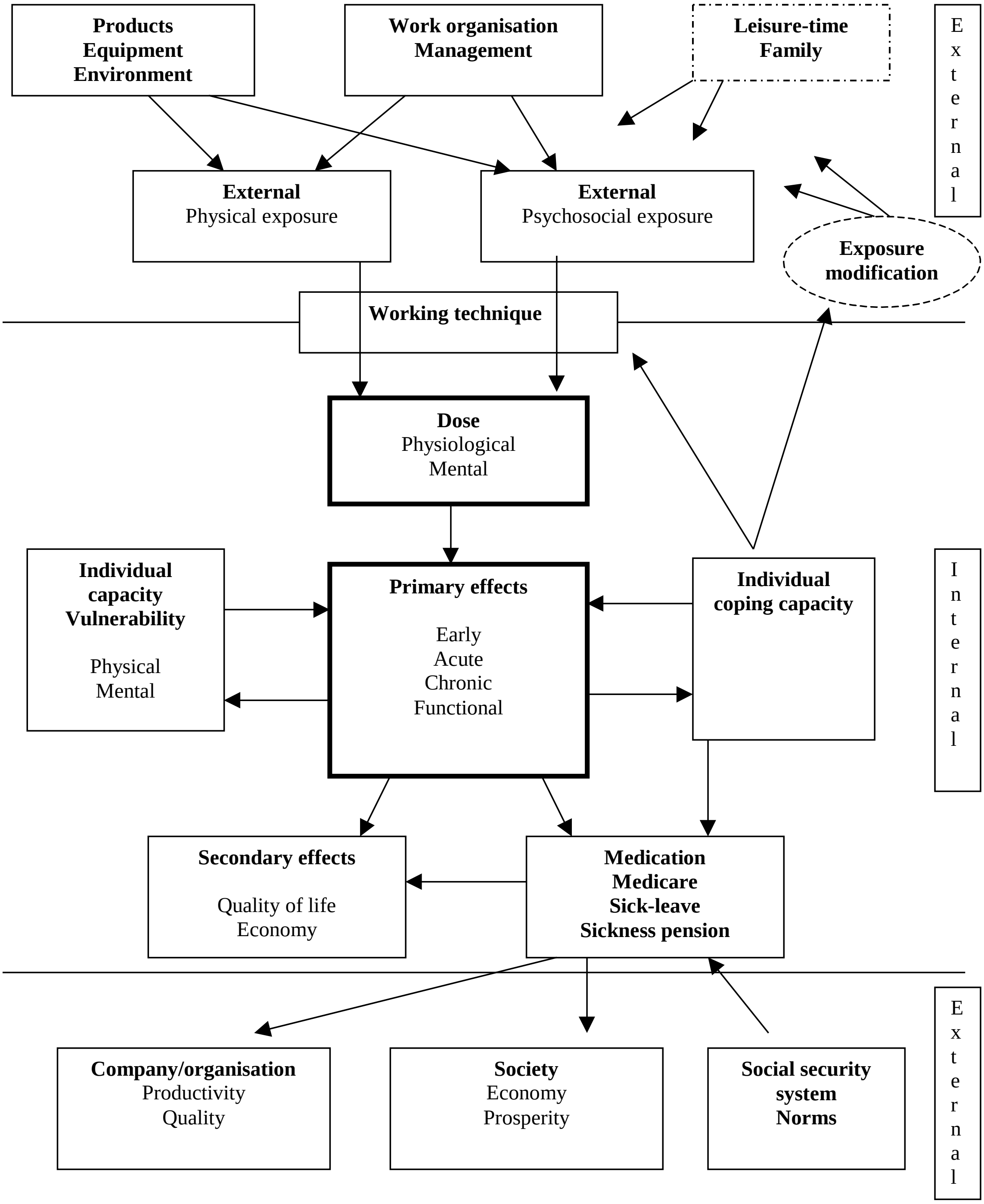


Figure 1. Suggested factors and their relations in the chain of development and persistence of musculoskeletal neck and upper extremity disorders and their secondary and external effects. ”External/internal”=factors external or internal to the subject.

The early/intermediate effects may be postulated as self-limiting or transient, e.g. (minor) changes in mental and/or physiological homeostasis. These could be perceived as, e.g. strain, discomfort, fatigue, tremor or (muscular) tension.

More prominent effects may be either acute (self-limiting or transient) or chronic with self-perpetuating, generalising or persisting damage processes to homeostasis and the tissue structures. Such acute or chronic effects may be perceived by the subject as pain or other symptoms and, often but not always, by external observers as signs in medical or laboratory examinations or as deficiencies of functional capacity. Serious pain and obstruction of the functional capacity can necessitate sick-leave and sickness pension. Sick-leave can be seen as a means for exposure elimination or a therapeutical and pain-coping measure. The use of sick-leave and sickness pension depends on the demands of the occupation. It also depends on laws, regulations, norms, and economic incentives in the community. Other coping measures are different symptom relieving activities, such as medication or medical consultation and care. Actions to remove or diminish or otherwise modify the unhealthy exposure or to improve the individual capacity or working technique are examples of adaptive coping activities. Effects on quality of life and economy are common secondary effects for the subject. Other secondary effects are seen on quality and productivity at company/ organisational level, economy and prosperity at community level.

1.5.2 Chain of effects

In a hypothetical cause-effect relation, as indicated in Figure 1, musculoskeletal disorders are seen as effects or outcomes of exposure in work life, in interaction with other exposures and individual capacity and coping abilities. These effects are manifold. They can be seen at individual or external levels and at different time intervals. The effects are coupled in a cause-effect cascade over time, i.e. one effect is the cause of the next [4]. The following example can illustrate this. Repetitive and forceful wrist movements causes increased pressure inside the carpal tunnel which in turn increases the intra-neural pressure of the median nerve, which causes a decrease in intra-neural blood supply, which causes cell-membrane instability, causing defective axonal transport and signal propagation and also electrolyte destabilisation, which cause oedema that cause further increase in intra-neural pressure, and so on… [34, 123, 164, 180, 201]. The defective axonal signal propagation causes (is perceived by the subject as) symptoms of numbness and tingling in the fingers; (can be observed as) positive nerve compression provocation signs, and (can be measured as) a decrease in median nerve conduction velocity over the wrist region. These symptoms can be regarded as “acute” reversible effects. Sustained high intra-neural pressure can cause chronic effects, such as a decreased function in 2-point discrimination (2-PD) ability and trophic changes in the thenar muscles with permanent damage, which can be observed as muscle weakness and thenar atrophy. The symptoms and dysfunction may cause decreased productivity and quality at work and a need for exposure elimination (sick-leave or exposure modification) and perhaps also medical care (surgery).

1.6 Affected structures, risk factors, pathomechanisms, symptoms, signs, and diagnoses

Primarily affected organs and structures in the neck and upper extremities can be divided into skeletal bones, joints with capsule, muscles, tendons and tendon sheaths, and peripheral nerves.

1.6.1 Skeletal bones and joints

Non-traumatic work-related disorders affecting the skeletal bones or joints in the neck and upper extremities are rare. Cysts and vacuoles in the palmar bones, degeneration of the lunate bone and arthrosis of the acromioclavicular joint have been reported from exposure to manual handling of heavy loads or forceful exertion and vibration/percussion [61, 72, 195].

Pathomechanisms The condition “arthrosis”, including its spinal counterpart – “spondylosis”, can be considered as a degenerative phenomenon with a decrease in articular cartilage or intervertebral disc thickness. The mechanisms are unclear, but high compressive joint forces e.g. from transmitted impulses from hand-held tools and/or due to forceful gripping or handling of heavy loads have been suggested [61].

Symptoms Mainly ache and pain on loading of the joint.

Signs Restriction of active and passive joint movement, tenderness and pain at loading.

Diagnosis “Arthrosis” or “spondylosis” is mainly based on X-ray findings.

1.6.2 Muscles

The neck and upper extremity muscles are active, not only on joint movements and exertion of forces, but also to counteract the force of gravity on the body segments and stabilising e.g. the shoulder and wrist joints during work [77, 82, 186, 187]. Neck muscles are also active during precision work, mentally demanding tasks or psychologically stressful situations [40, 45, 122, 125, 218, 226, 243].

Pain in the neck and shoulder area with tenderness over the descending part of the trapezius or other adjoining muscles is more common among women than men and is described in association with repetitive work, lack of pausing, static load and constrained head and arm postures [72, 73, 104, 163, 210].

Pathomechanisms The supraspinous muscle is vulnerable as it is partly located in a compartment. High intramuscular pressure which obliterates the blood support is found already on light abduction or flexion of the shoulder joint [90, 95]. One study reported tight surrounding fascias and high intramuscular pressures at low loading, also in the trapezius muscles among patients with trapezius symptoms. This disappeared after pressure-releasing surgery [74].

The pathomechanisms involved in the development of most work-related disorders in the muscles are unclear, however. Several, not necessarily mutually exclusive, models and hypotheses have been put forward. One is about “muscle overload and energy crisis”. It is suggested that prolonged static contractions of the trapezius muscle will result in an overload of the type-I muscle fibres with increased fatigue [71, 76, 113, 114, 118, 119]. Damage to type-I fibres could also be explained by a muscle activation pattern where the motor units are activated in the same order on increasing force demands, resulting in prolonged periods without breaks for specific units (the “Cinderella” theory) [86].

A“mechanical-chemical damage” model is suggested where muscle fibres are damaged from eccentric muscle contractions, perhaps due to unhealthy working technique with an imbalance between agonist/antagonist muscles [43, 58]. Calcium ions and free radicals may cause tissue damage as they are produced in injured or re-perfused hypoxic muscles [3, 88, 105].

The “gamma motor neurone” model describes how muscle tensions can be spread to larger muscle areas, both ipsi- and contralaterally. This process can be triggered by noxious stimuli, e.g. ischaemia or muscle damage that stimulates the muscle afferents. This rise in muscle activity leads to further production of metabolites and a further stimulation of the muscle afferents in a self-perpetuating process [38, 91].

Noxious stimulation due to tissue damage and/or inflammatory reactions can trigger a successive release of different neuro-hormones and peptides that starts a pain and inflammatory augmenting circle. This results in primary peripheral and secondary spinal hyperalgesia including enlargements of receptive fields and sensitisation not only to noxious stimuli but also to non-noxious stimuli, such as cold and touch [124, 156 for overviews].

Symptoms Ache, feelings of stiffness, weakness and fatigue together with pain on muscular contraction.

Signs Local tenderness, stiffness, pain on muscular contraction or passive distension. Nodules that trigger radiating discomfort or that are localised tender points.

Diagnoses Local “myopathies” or more regional “myofascial syndromes” are found. Many cases are “unspecific” where no diagnosis is possible other than symptom-relating e.g. “cervicalgia”, “brachialgia”. Other relevant diagnoses should be ruled out.

1.6.3 Tendons and tendonsheaths

Affections of tendons and their sheaths are common in the shoulder, elbow and wrist regions. There is strong evidence, including experimental, for work-relatedness regarding rotator cuff tendinitis where repetitive manual work, working postures with elevated or abducted arms and static load are risk factors. Risk factors for wrist tendinitis are forceful and repetitive gripping or extreme joint postures [11, 67, 72, 104, 191].

Pathomechanisms Friction and traumatisation due to repetitive movements of the tendon past edges or narrow spaces is one main mechanism explaining inflammatory reactions leading to tendinitis. Others are microruptures in the tendon or its insertion in the bone due to forceful stretching of the tendon. There are special anatomical locations, with vulnerable blood supply and degeneration of the tendon tissues, that predispose to such reactions, such as the supraspinous tendon.

Symptoms Ache and pain on stretching of the tendon.

Signs Tenderness at the affected tendon. Pain on resisted muscular contraction or passive stretching of the tendon are common findings. Sometimes there are local thickenings on the tendon which makes the tendon stuck in narrow passages, such as the supraspinous tendon passing under the acromion (painful arc) or wrist/finger extensor tendons passing into sheaths (tendinitis stenosans). “Tenosynovitis” may be followed by crepitations on movement.

Diagnosis “Tendinitis”, “peritendinitis”, “myotendinitis” or “tenosynovitis” depending on the affected structures. Most common are rotator cuff tendinits, epicondylitis, and de Qurvain´s tendinitis. Common diagnostic criteria are - adequate symptoms and signs of local tenderness, pain on resisted muscular contraction or passive tendon stretching.

1.6.4 Peripheral nerves

Compression or other mechanical traumatisations are, apart from toxic and vibration-induced neuropathies, the main causes of work-related disorders of the peripheral nervous system. Best documented is the carpal tunnel syndrome affecting the median nerve. Extreme wrist postures and repetitive motions or forceful gripping are risk factors [11, 72, 104]. Another is compression of the brachial plexus, often called “thoracic outlet syndrome” (TOS). Cervical ribs or other anomalies in the neck/shoulder region and neck trauma increase the risk of such compression. A few cross-sectional studies indicate that manual work or repetitive arm-movements are risk factors [73, 202]. Work with hand-held vibrating tools has been associated with compression of the median nerve in the carpal tunnel [233]. Few studies are found concerning association between such work and compression of the brachial plexus [96].

Pathomechanisms See section 1.5.2 (example).

Symptoms Pain, numbness and tingling sensations in the specific areas of the distribution of the compressed nerve. In severe cases weakness of muscles. Subjects with compression of the brachial plexus may have widespread symptoms, both in the neck/shoulder regions and most typically, in the ulnar distribution of the forearm and hand [174]. The pain is more dull and diffuse on compression of predominantly motor nerves, e.g. the posterior interosseus nerve. Symptoms are often provoked by specific circumstances, e.g. carpal tunnel syndrome during sleep, compression of brachial plexus when working with elevated arms [123, 161].

Signs In severe cases there is decreased muscular strength and wasting of affected muscles. Tinell´s sign, decreased 2-PD capacity and sensitivity to touch and vibrations may be found. Diminished tendon reflexes are rare.

In early phases, such as among a working population, signs may only be observed through specific compressive provocation tests. The Abduction External Rotation (AER) test has been used for provoking compression of the brachial plexus [153, 173, 182]. The use of the AER test has mainly been reported from different patient groups. Few studies have reported the outcome of this test among the working population or specific exposure groups [202]. No studies report prospective aspects of the AER test. Of specific interest would be prognostic factors for the incidence of new brachial plexus compression, as measured with the AER test and the prognosis of a positive test.

Diagnosis Diagnostic criteria for most of the compressive disorders have been debated. The carpal tunnel diagnosis relies mainly on median nerve distribution of symptoms and a positive nerve conduction test. No valid nerve conduction test has been found for evaluation of compression of the brachial plexus. The diagnosis of TOS relies therefore on symptoms and signs, mainly in the AER test [123, 161]. Other relevant diseases should be ruled out.

Nerve compression diseases are not always easy to diagnose. Peripheral nerve entrapment, radiculopathy and TOS were three of the five most frequently overlooked diagnoses among chronic pain patients referred to a pain clinic [81].

1.6.5 Other relevant diseases and unspecific disorders

Symptoms described above can, however, also emanate from other pathological processes. Well-known are myocardial ischaemia or other diseases affecting the peritoneum, pleurae or pericardium that can be referred to the arm or shoulder region due to their support from the phrenic nerve (C3-C5).

On the other hand, there are situations when symptoms emanating from structures in the neck and upper extremities are referred to other regions in the body. Examples are headache or vertigo due to disorders of the cervical spine and muscles or compression of the brachial plexus. Affections of deep structures in the neck/shoulder region can be referred to the frontal or posterior thorax and upper extremities [100].

Symptoms and signs can also be manifestations of obvious trauma, e.g. whiplash injury, but also of systemic diseases or other medical conditions. Well-known are aches in the joints due to rheumatoid arthritis, psoriasis or other collagenosis. Widespread ache and pain is suffered by patients with fibromyalgia. Carpal tunnel disease is seen among diabetes patients and during pregnancy. Ache and pain from the muscles are sometimes found among patients with hypothyreosis, tumours in the hypophysis or other malignancies. Polyneuropathy, e.g. due to alcohol or other toxic exposure, can cause numbness in the hands. Common is also ache and pain during or after infections, viral, bacterial or others, e.g. Borrelia burgdorferi. Examination and evaluation of neck and upper-extremity disorders should always have these alternatives in mind.

It should finally be mentioned that in many cases of pain or other symptoms from the neck and upper extremities there are no, vague or contradictory signs at examination. Sometimes the symptomatology is also vague or contradictory, and they add to the many unspecific cases where a definite diagnosis is not possible. These cases are numerous and are given different names – “cervicobrachial disorder”, “neck myalgia”, “cumulative trauma disorder” etc. Future studies will hopefully bring more light to this field so that these cases can be better understood and properly diagnosed. This could facilitate rehabilitation and prevention.

1.7 Location of work-related neck and upper-extremity disorders

1.7.1 Disorders associated with physical exposure

The specific locations of acute or chronic WRMSD are mainly restricted to the specific musculoskeletal structures primarily affected by the (unhealthy) working postures, movements, and physical loads. These main locations have been described above in section 1.6. It was also described in section 1.6.2 how muscle stiffness can spread both ipsi- and contralaterally and how local pain can spread to other structures and locations, enlarging the painful region and prolonging the pain.

The locations of the affected structures, the symptoms and the findings on physical examination, often but not always coincide. The phenomenon of “referred pain” makes symptoms more diffuse, widespread, and distal [117]. Referred pain from injury to peripheral nerve cords, stimulating the nervi nervorum, can be referred both distally and proximally, e.g. in carpal tunnel syndrome [211]. Compression of peripheral nerves makes symptoms typically more distal.

1.7.2 Disorders associated with psychosocial exposure

The location of affected structures, symptoms and signs associated with mental load and (unhealthy) psychosocial conditions is less documented. Primarily, the causal relations are unclear. Hypotheses emanate from theoretical postulations, laboratory studies and observations of psychosomatic disorders. Pain and disorders secondary to frequent or long-lasting muscular tensions or static contractions without pause, as a reaction to mentally stressful exposure and not due to a external physical load, constitute a common theory [48, 205, 216, 223, 227]. The theory is however not yet developed enough to specify *where* these tensions and pains would be located in the body. One of the pioneers of psychosomatics, Wilhelm Reich, described in 1933 a "muscular armour" with a segmental distribution of tensed muscles in the face, neck, trunk and pelvis as a reaction to deep frustrations [169]. Symptoms among workers with psychosocial problems are reported to be restricted mainly to the neck and shoulder regions [229]. Elevated electromyographic activity has been recorded from the neck, trapezius and erector spinae muscles during stress provocation among patients with pain syndromes in the cervical or back regions, respectively [54, 55, 189, 190, 243]. Elevated muscle activity has also been reported from the trapezius muscles during experimentally-induced mentally demanding tasks [45, 122, 217, 226, 230]. The theory of stress-induced muscular tension and/or lack of ability to relax as a mediator of the effects of poor psychosocial work conditions predicts the findings of muscular pain and tenderness among subjects working in such conditions. Symptoms and signs from joints, tendons or compressed nerves are not primarily consistent with this theory, as affections in these structures are thought to be associated mainly with high, long-lasting or repetitive physical load [11, 72, 104].

No reports were found of studies addressing associations between psychosocial work conditions and *specific locations* and *characteristics* of MSD.

1.8 Quality aspects of assessments

All data in epidemiological studies about disorders are only estimations and approximations of hypothetical “true” states of disorders among the subjects. There are many sources of error in these estimations.

1.8.1 Reliability

Random variations in time and between subjects and within subjects are common to all measurements of disorders due to the nature of biological processes and other sources of variation during the measurements. The degree of freedom from random errors in the estimations is expressed as the “reliability”. Reliability is measured as stability over time - “test-retest” or “intra-observer” reliability - and as the combined stability over time and between measuring instruments, e.g. observers, - “inter-observer” reliability. Calculations are made using different measures of association, e.g. correlation or kappa coefficients (κ) [52, 112].

Lack of reliability in measurements of disorders introduces uncertainty regarding the estimate and an attenuating bias to risk estimates. This uncertainty makes the results of all further analyses uncertain and less powerful. It is therefore important to minimise random errors. One method is to make average estimations based on repeated measurements. Other methods are to increase the quality of measurements, e.g. more precise question formulations in questionnaires or standardisation of medical examination procedures.

1.8.2 Validity

The degree of freedom from systematic errors in estimation of the true disorder state is expressed as the “validity” of the measurement. Sources of systematic errors could be e.g. selective drop-outs from the study group, frequently misunderstood questions in a questionnaire or non-proper medical examination techniques.

Systematic errors can introduce unpredictable bias to the results. Such bias will misinform and lead to erroneous conclusions. Systematic errors should therefore be avoided as much as possible. Good reliability is a prerequisite. One approach is to get "as close" to the conceptually "true" condition as possible, e.g. acquire data from the insurance company registers about sick-leave instead of using a questionnaire where recall bias could be systematic (forgetting). Other examples are to use standardised medical examination procedures and to do repeated "calibrations" of the examiner (-s) against a "standard examiner" or a peer group, reaching consensus about methods and criteria. It is also important to avoid selective sampling or drop-out errors. For example, if healthy subjects are less prone and disordered subjects more prone to enter a study there will be an overestimation of the prevalence of disorders. If disordered subjects have left the company or are not available for examination (on sick-leave due to the disorder!) then there will be an underestimation of the prevalence of the disorder (healthy-worker effect) [151, 178].

The ability of an assessment method to identify "true" cases of the disorder is called the "sensitivity" and the ability to identify all non-cases is called the "specificity". Further, the proportion of the estimated cases that are "true" cases is called the "positive predictive value" (PPV).

The validity of the estimations can be calculated using different measures of association between the estimate and the "true" value or its proximate ("golden standard"), e.g. correlation or κ coefficients (criterion or prospective validity**)**. If there is no "golden standard", the estimate can be compared to other phenomena that are closely related to the disorder (construct validity). The validity of a test with a dichotomous outcome is optimally expressed as its likelihood ratio (sensitivity/1-specificity). The corresponding measure concerning continuous tests is the Receiver Operating Curve (ROC) (sensitivity plotted against 1-specificity) [6].

Errors in assessment can be systematic also in another perspective in risk-analytical studies. If errors in assessment of the disorder differ systematically between subjects who are exposed versus those who are not exposed to the risk-indicator, there will be an "exposure-dependent misclassification of disease" [151, 178]. This will introduce bias to the measures of association between exposure and disorders (over- or underestimation). Thus if exposed subjects tend to overestimate the disorders more than non-exposed subjects, then there will be an overestimation of the true association between exposure and effect. Freedom from exposure-dependent misclassification is therefore important in analytical studies.

If, in *analytical* studies, there is no bias in assessment of disorders associated with the considered exposure, then the effects on the relative risk estimates because of misclassification of disorders could be described as follows. Low *sensitivity* will not influence the relative risk estimate in cohort studies measuring prevalence or cumulative incidence. If the comparison is based on incidence rates, there may be a certain diluting effect, which is negligible unless the incidence of the sign is high [151, p 31]. When estimating odds ratios, for instance in case-control studies, such misclassification introduces bias towards the null value, which might be considerable if the incidence or prevalence of the sign is high [178, 87]. Low *specificity*, on the other hand, will have a considerable diluting effect on the relative risk estimates in all circumstances. This underestimation will be marked if the prevalence of the disorder is low [20, 151].

Applied to section 1.4 above, about diagnoses and "proxies", this means that the generally most important quality of such ("proxy") diagnoses is high *specificity*. Signs, diagnoses and "proxy" diagnoses should not be aggregated so that cases and non-cases are lumped together. A crucial complicating factor is, however, that the underlying pathological condition and disease is often unclear. There is thus seldom a "golden standard" to rely on. This is also true for signs and tests of function.

1.8.3 Rating bias

Quantitative data about exposure factors and disorders in epidemiological studies are often acquired by subjective judgements or ratings. In the science of psychometrics the rated phenomena are called "stimuli" and the resulting judgements or ratings are here called "ratings"[2]. "Stimuli" in the context of epidemiology could include exposure factors, potential confounders (physical, psychosocial etc.), and outcome phenomena such as number of sick-leave days, pain intensity, etc. "Ratings" would be the overt judgements or ratings of these phenomena as a result of a perceptual and cognitive process which by its nature must be described as subjective. Such judgements or ratings could be given as verbal expressions, as free numerations or as values in rating scales.

The relation between stimulus and rating magnitudes has been described by S.S. Stevens and G. Ekman as a power function [46, 196]:

$$R=b+a*S^n$$

where S=stimulus magnitude ; R=rated magnitude; n=exponent; a, b =constants

Such stimulus-rating functions have been empirically stated for many stimulus modalities [44, 197]. There are, however, many sources of error and biases, random or systematic, in subjective judgements and ratings [162]. One of the sources of systematic bias is individual differences in the use of rating scales and the use of numeric values. Such differences in rating behaviour are well described in psychometrics, mainly concerning the *range* and *standard deviation* of numerics in ratings [16, 47, 66, 93, 203]. The spread of ratings used by each subject affects the exponent in the power function mentioned above, with a higher spread resulting in a higher exponent.

Individual differences in the *average value* of the numerics used in rating procedures are however less studied. Such differences in rating behaviour could be described as a stable trait, a general tendency, to use high or low numerics when rating different phenomena, or as "over-" or "under-estimators" if the ratings concern phenomena with true values. High raters would have a higher exponent in the algorithm above (Figure 2). Applied to epidemiological studies, high-raters would rate *both* exposure and outcome as higher than low-raters and vice versa, even when there are no differences in exposure or outcome. If in a hypothetical study there is a range of such rating behaviour among the subjects, and both exposure and outcome are rated by the same person (usually the subject of study), this would introduce an association between the exposure and outcome ratings (Figure 3). This association would, however, solely be an effect of rating behaviour, an artefact that would introduce bias to the results. Estimates of relative risk would be overestimated, in typical cases where both exposure and outcome measures are scaled in the same direction. Differences in the spread of ratings among subjects can likewise introduce similar bias to relative risk estimates.

[2] The proper term is "response". This term has, however, another definition as an effect-measure in traditional epidemiology, why it is avoided here in order not to cause confusion.

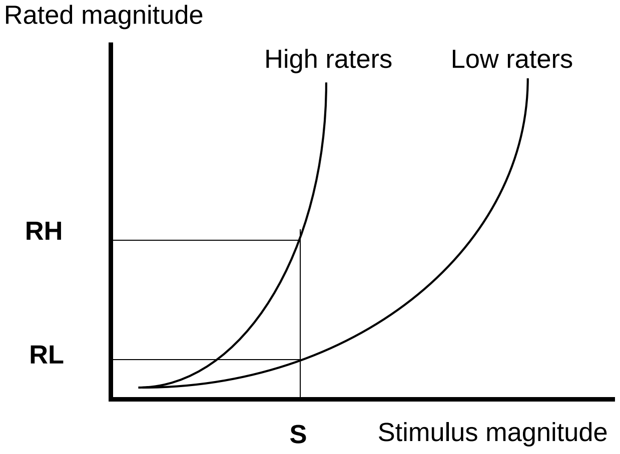


Figure 2. Power functions for the relations between the stimulus and the rated magnitude among the hypothetical high and low raters. A specific stimulus magnitude (S) is associated with a higher rated magnitude among high raters (RH) than among low raters (RL).

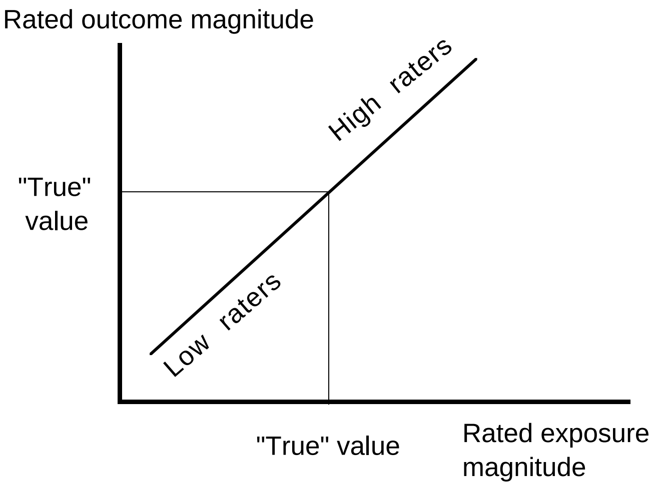


Figure 3. Hypothetical false association between rated exposure and outcome magnitudes among subjects with a range of high and low raters. All the subjects have the same ”true values” on both the exposure and outcome variables.

If only one of the components, exposure or outcome, is rated by the subject, high and low rating behaviour would bias relative risk estimates towards unity, because of its random relation to the true values.

No studies in epidemiology have been found regarding the existence and the potentially uncontrollable biasing effect of such postulated high and low rating behaviour.

1.9 Assessment of musculoskeletal disorders

Data on disorders in epidemiological studies are mainly of the following types:
- -medical history
- -symptoms, discomfort and related data
- -signs on medical examination
- -"diagnoses", syndromes
- -other effects (function, sick-leave, life quality etc.–not further commented in this thesis).

1.9.1 Medical history

Medical history about past trauma, diseases, surgery, medication, sick-leave etc. constitutes important information for the understanding of the current disorder. Prior sickness is often the most important risk factor. Relapses are common. Retrospective information from the subjects is affected by recall bias and other memory problems, such as the "telescoping effect" (phenomena are recalled as being more recent) [212 p 398]. Register data to compare with are sometimes available, e.g. from the company health care unit and local insurance offices.

The reliability and validity of medical history data diverge. The test-retest reliability of interview and questionnaire data has been reported to be good or excellent for well-defined past chronic or serious diseases or continuous medication, e.g. myocardial infarction (κ>0.8; at prevalence of disorder=4%) and fair for less-defined medical conditions or intermittent medication, e.g. chest pain (κ<0.6; prev.=9%) [101]. Memory problems (under-reporting) can be expected to decrease the sensitivity (=0.3-0.9) of information about, e.g. hospital admission, fractures, chronic illness or medication. Specificity (=0.9-1.) and PPV (=0.4-1.) are mainly high. Marked differences in validity have not, with a few exceptions, been found between gender, age groups, educational levels or social classes. There are varying reports about the effect of recall time on validity [78, 99, 152].

Test-retest reliability for questionnaire-based information among active workers about previous (ever) rotator cuff or carpal tunnel syndrome, tendinitis, sprain and arthritis were "good-excellent" (κ=0.6-0.9; prev:=5-20%) [56]. The sensitivity for past (three years) back pain with sciatica was 0.74 and lumbago 0.60 in a study of 2200 male machine operators, carpenters and office workers. A tendency to exposure-dependent misclassification was found, with lowest sensitivity among office workers [172].

Test-retest reliability of retrospective data about sick-leave due to musculoskeletal disorders is reported as high among population samples (κ=0.7-0.9; prev=15%). The validity values were also high (κ=0.8; sensitivity >0.8; specificity >0.9) and no exposure dependent misclassification was found [1, 22, 57].

1.9.2 Symptoms and discomfort

Central to the evaluation of musculoskeletal disorders are the symptoms. Symptoms are defined as "any subjective evidence of disease or of a patients condition, i.e. such evidence as perceived by the patient…" [39]. Symptoms are by definition subjective phenomena within the suffering subject. As information about symptoms depends on the perceptions and communications of the patient, it can be affected by factors that influence such processes, e.g. memory, fears, motivation, language etc. This can introduce both dependent and independent misclassification of the data in an epidemiological study. One method to minimise such bias is to ask for specific information of symptoms i.e. "where, when and how?”, e.g. “numbness in the right hand fifth finger within 1 minute when working with hands above shoulder level” (indicates compression of the brachial plexus).

The symptom that has been given most attention in scientific studies is “pain”. There are many studies and much literature about the assessment of pain, chronic pain, and low-back pain [13, 212 for overviews]. There is less literature about other symptoms than pain and other locations than the low-back region.

The term “discomfort” is frequently used as an “umbrella” term for different unpleasant sensations and symptoms [24 for review]. Phenomena such as “pain”, “tenderness” and “fatigue” are often included which makes the delimitation between “discomfort” and “symptoms” very vague.

The reliability of symptom data seems to be good, according to the few studies available. Test-retest reliability was good-excellent for questionnaire-based data (“Nordic Questionnaire”) on symptoms from the neck and upper extremities among active workers (κ=0.6-0.9; prev.=10-30%) [56]. No association to reliability was noted with gender, age, educational level, seniority, or exposure to repetitive work. Other test-retest studies of the “Nordic Questionnaire” have reported a range of non-identical answers varying between 0-26% between different body regions [37, 110].

Ratings of experimental provocation of neck- and arm-discomfort are fairly stable over 2 weeks (Borg CR10 scale r>0.70) [221]. Test-retest (3 weeks) reliability of VAS-rated neck and upper-extremity discomfort at work was studied among industrial workers [56]. Reliability was good if subjects were asked to rate worst discomfort during the previous 30 days, but poor if they rated current discomfort.

Validity of symptom data has been studied from different aspects. Questionnaire data have been compared with interview data. A study of a questionnaire-based diagnoses for episodic tension headache among population samples reported low sensitivity (0.4) but high specificity ($\approx$1) compared to medical interview symptoms recorded by a physician (prev.=66%) [166]. Questionnaire data about epicondylitis or tenosynovitis/peritendinits during the previous year among meat processing factory workers were compared with occupational health care records. The sensitivity was 0.5-0.6, specificity about 1 and the PPV about 0.5 (calculated from published data; prev=5%) [111].

Validity of symptom data has also been studied against signs on medical examination. The sensitivity of the Nordic Questionnaire to identify subjects with signs on medical examination (prev.=25-75%) varied between 0.4-0.8, and the specificity was mainly above 0.9 in a study of neck and upper-extremity disorders among female workers with many occupations [155]. Pain on palpation or provocation of muscles and tendons in the neck/shoulder and forearm was positively associated with a pain-index based on questionnaire data from the same regions [127]. One other study of elderly people reported κ-values around 0.6 for interview-based data regarding pain and restrictions of joint movements compared to findings in a medical examination [36].

1.9.3 Characterisation of symptoms or discomfort

Information about type or quality of the symptom, e.g. ache, pain, stiffness, tightness, tingling, numbness etc, is often necessary for understanding and for diagnostics. The reliability of such data specifying the type or quality of symptoms varies however and is inconsistent between different regions of the body [56]. This indicates that assessment of symptom data should be aggregated concerning symptom type or quality. One of the most used pain assessing instruments, however, the McGill Pain Questionnaire, is based on appraisal of 87 words describing the type and affective connotations of the pain [141, 142].

Symptom data about musculoskeletal disorders should be assessed separating different body regions. Regarding the neck and upper extremity regions, data are usually separated for (left-right) neck, shoulder, upper back, shoulder joint, upper arm, elbow, forearm, wrist, hand, and fingers. To specify and define the partitions of the different regions, questionnaires are often supplied with a body map showing the delimitation of the regions. One common questionnaire is the ”Nordic Questionnaire” (Figure 4) [110]. Others use slightly different definitions and body maps [29, 127, 133, 199].

1.9.4 Symptom magnitude

Quantification is done in epidemiology e.g. when studying dose-response relations. A more intense or long-lasting pain is assumed to be related to a higher magnitude of effect. Symptom magnitude can be assessed using data about:

- intensity of symptoms
- duration or other temporal aspects of symptoms
- use of analgesics, medical consultations, sick-leave due to symptoms
- consequences of the symptoms for work life, leisure time, social activities, sleep.

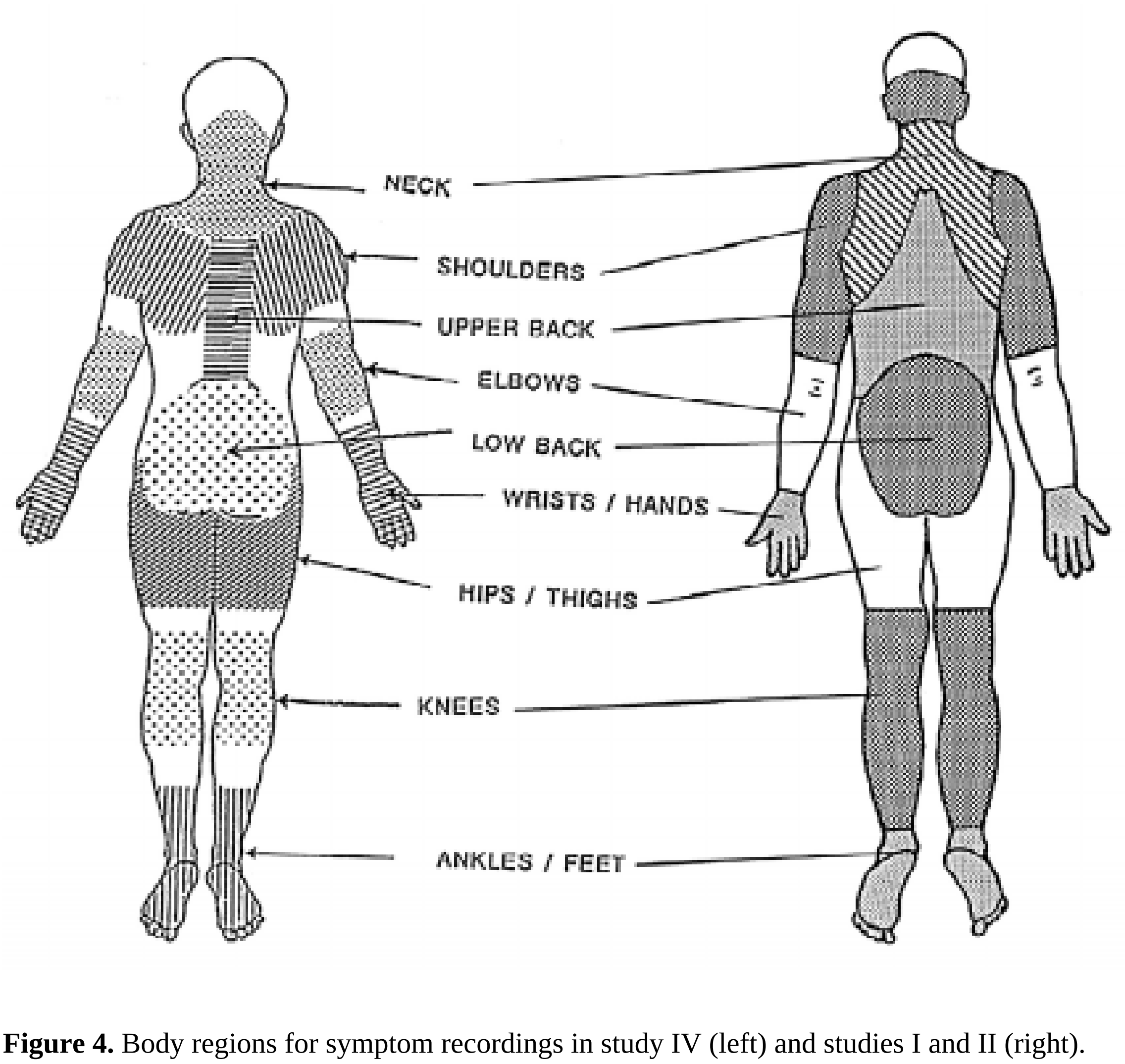


Figure 4. Body regions for symptom recordings in study IV (left) and studies I and II (right).

Intensity has been assessed with different rating scales. Most used are category scales, such as the Borg scales [14, 15]. An often-used ratio scale is the Visual Analogue Scale (VAS) [188]. Intensity can be rated as "current", "worst during the last 6 months" "average during last week" etc. [242].
Duration of symptoms (since onset) can be assessed simply as days, weeks, years etc. Other aspects are continuous or intermittent symptoms. Three to six months has been suggested as criterion for "chronic" pain [69, 143].

Pain that prompts use of analgesics is probably more severe than pain that does not. The same reasoning could be applied to pain and medical consultations, treatment or sick-leave. The number of sick-leave days and doses of analgesics can be used for quantification. Such pain-relieving behaviour is however also dependent on the coping manner of the subject and other factors such as the social security system.

Finally, severity can be assessed as the consequences of the symptoms. Pain that disturbs the sleep can be quantified as number of nights with disturbances. Other consequences are interference with work capacity, productivity, and quality. Interference with leisure time activities, family, sexual and social life are other common phenomena that are related to the severity of the symptoms.

1.9.5 Symptom recording methods

Symptoms, discomfort and medical history are most often recorded in self-administered questionnaires. Interviews, e.g. traditional medical interviews or telephone interviews, are also used, but are more resource-consuming. Diaries and pain loggers are other methods that are intended to increase data quality as the recordings are made intermittently during the day. Applications of psychometric knowledge have been fruitful and there are guidelines for the design of good questionnaires and interview guides [49, 126, 137, 198].

1.9.6 Pain drawings

Pain drawings have frequently been used clinically for communication and documentation of pain, ache and other symptoms and as tools for diagnostics, therapeutical decision-making and prognostics [2, 138, 157, 179]. The stability and reliability of evaluation of different pain drawing characteristics are generally high [130, 132, 214]. Their validity has been studied in relation to symptoms, signs, laboratory findings and diagnoses [5, 25, 213, 246].

The essence of pain drawings is the communication of the spatial distribution of symptoms, projected on the body surface. The congruence of the distribution with well-defined anatomical regions ("organic","anatomic") in contrast to more atypical, diffuse or exaggerated distributions ("non-organic", "idiopathic", "psychogenic") are characteristics that have been studied [2, 5, 63, 165, 214]. Studies have mainly focused either on neurogenic (sciatica) or "non-organic" pain in the low-back region. Less attention has been paid to other pain drawing characteristics or the distribution of nociceptive pain in other body regions such as the musculoskeletal system in the neck and upper extremities [98, 131, 184].

As mentioned earlier, different possible mechanisms enlarge the painful region from noxious stimulation or otherwise affect the location. Intense or long-lasting focal pain could thus hypothetically be generalised to larger areas and to both sides of the body. Pain drawings could be one method to study such phenomena of symptom location and distribution.

Besides areas covered by the markings in pain drawings, few other attempts have been reported regarding quantification and “objectification” of pain drawing characteristics. The use of “objective” and quantitative measures in the characterisation of pain drawings could be one step in the endeavours to make more reliable and valid use of information about the phenomenon of pain.

Finally, most studies of pain drawings have reported its qualities in clinical settings among patients suffering from pain. The merits and usefulness should be evaluated also for use in occupational health work and in epidemiological studies of specific occupational exposure groups or the general population.

1.9.7 Signs

Signs are generally considered to be more “objective” than symptoms. Most medical examination tests have more or less subjective components, however. This subjectivity is two-fold. Primarily the execution and evaluation of examination manoeuvres are dependent on the skills, perceptions and evaluations of the examiner. Secondly, the completion and outcome of most examination items depend on the co-operation, perceptions and evaluations of the examined subject. The difference between symptoms and signs is sometimes small, e.g. palpation of tenderness. Tenderness is a symptom that is dependent on a specific provocation, in this case mechanical pressure on the tissues. The main difference between tenderness as a symptom and as a sign concerns who delivers this pressure. Similar conditions concern other examination items that work by provoking pain or assess the sensitivity for weak stimuli. There are methods to minimise the subjectivity of the examiner, e.g. use of a goniometer or an algometer. Other ways are to standardise the examination procedures and training of the examiners. There are many guide-books for medical examination of the muskuloskeletal system [83, 139].

A medical examination as part of an epidemiological study of musculoskeletal disorders may include the following types of examination items:

- inspection
- assessment of range of movement
- provocation of pain at stretching of muscles and tendons.
- provocation of pain at muscular contraction
- assessment of muscular strength
- provocation of tenderness at palpation
- provocation of nerve compression or other nerve stress tests
- other tests e.g. tremor, sensitivity (touch, vibrations, 2-PD).

Inspection. The main items are evaluation of stature and difficulties during movements, such as in walking or making gross manoeuvres. The posture of the neck and shoulder asymmetry is often registered. Atrophy of muscles may indicate serious disease. Gross deformities e.g. a callus after a fracture of the clavicle or a wrist ganglion can help explain compression of nearby nerves. The inter-examiner reliability of inspection of muscle atrophy and other signs in the neck and upper extremities has been studied and found to be low among neck patients (κ=0.3-0.5; prev.=5-30%) [235] and among the working population (κ=0.3; prev.=10%) [8].

Range of movement. Range of joint movement (ROM) is most often measured in degrees of an angular rotation around an axis. Definitions of terminology, neutral position and axis of movement together with normative data about ROM are published e.g. by American Academy of Orthopaedic Surgeons [64]. ROM is measured during both maximum active (unassisted) and passive (assisted by examiner) joint movement. Naked eye assessment of ROM is most often estimated as “normal” or “reduced”.

Naked eye estimations has been reported as both unreliable and invalid in some studies [79, 121, 145]. Other studies of the inter-examiner reliability of active neck ROM among neck patients found it to be fair-good (κ=0.4-0.6; prev.=5-20%) [235] and good among working population (κ=0.6; prev.=4%) [8]. The use of goniometers markedly increases reliability and validity if they are used in a standardised manner (test-retest r>0.90). There are no significant differences in measurement quality of different goniometers, only in their application [59 for overview]. The *inter*-examiner reliability (wrist-ROM CV=6-10%) is somewhat lower than the *intra*-examiner reliability (5-8%). Passive ROM is less reliable than active, due to differences in application of stretching forces to the tissues. There are also differences between joints. Joints with many axes of motion, e.g. the wrist, are more difficult to measure reliably and validly than single-axis joints, e.g. the elbow.

Tests of ROM can also be included in tests of upper-extremity function. Well-known is placing the hand on the neck as a test of shoulder abduction and external rotation. There are examples of further refinements of such tests suitable for epidemiological studies of functional ability of the upper extremities [28].

Provocation of pain on muscular contraction or passive stretching of tendons. Stretching of inflamed muscles, tendons or tendon insertions is painful. Stretching can be passive through the examiner´s pull or active through contraction of the affected muscle. A positive test is most often indicative of “tendinitis” or “myotendinitis”.

Muscle strength. Decreased muscle strength compared to the normal age and gender values can be a secondary phenomenon due to acute pain or muscular waste due to long-lasting pain. It may also be decreased due to deficient neuromuscular control, caused by e.g. compression of the efferent nerve. It can finally be an indication of a serious muscle disorder, which is rather uncommon.

Muscle strength in the neck and upper-extremity regions is mainly assessed in the deltoid (C5-C7) and rotator cuff muscles including the biceps (C4-C6), the forearm flexors and extensors (C5-C8), grip or pinch strength, and the finger abductors/adductors (C8). The maximum strength is usually assessed through application of manual resistance and is subjectively evaluated as “normal” or “decreased”, often using the other side of the body for comparison. Special rating scales are available for more detailed quantification of muscle strength [62, 170]. The reliability of evaluation of manual strength testing of shoulder, arm and hand muscles was found fair to good among neck patients (κ=0.4-0.6; prev.=5-30%) [235]. Except for grip (or pinch) strength, there are no convenient muscle strength measuring instruments for epidemiological use. The reliability of grip strength instruments is good [7].

Tenderness. Tenderness is a main sign of inflammation or other painful affections of the musculoskeletal system. Its main advantage is that it gives direct information about the location of the painful structure, thereby guiding to pinpoint which structure is disordered. Palpation, superficial or deep, or percussion of tenderness is therefore perhaps the most universally used examination method for many structures - bones, joints, muscles, tendons and nerves.

Unfortunately the literature shows that palpation of tenderness has varying reliability. Inter-examiner reliability among neck patients ranged between poor-good (κ=0.2-0.6; prev.=10-20%) in different locations [235] and fair among the working population (κ=0.5, prev.=5%). Algometers, with which applied pressure can be controlled, have been used for the assessment of the pressure pain thresholds, a measure of tenderness. Reported reliability is good [168].

Provocation of compression of nerves. Compression of peripheral nerves is in early stages often intermittent and restricted to provoking situations. Nerve compression tests are designed to provoke similar compressions in a controlled manner. The nerve roots are compressed with the "neck compression test" [192], the brachial plexus with the Abduction External Rotation (AER) test [173], and the median nerve at the wrist with Phalen´s test. Inter-examiner reliability of the neck compression test was fair-excellent (κ=0.4-0.8), specificity 0.9-1. and sensitivity 0.4-0.6 using a combination of neurological and radiological signs as criteria for "true" root compression (prev.=58%) among neck patients [236]**.** The validity of the Phalen´s and other nerve compression tests has been questioned [33]. One study of the inter-examiner reliability of the AER test found it to be good among the working population (κ=0.6; prev.=10%) [8].

Other tests. Tests of the function of the peripheral nerves include tests of sensitivity to pain, to light touch and to vibrations. A study among neck-patients found fair-good inter-examiner reliability (κ=0.4-0.6; prev.=10-40%) [235].

Many other tests are available for assessment of early or late aspects of musculoskeletal disorders. One example is measurements of tremor as an indication of fatigue [60].

1.9.8 Self-administered examination of signs

Data collection in epidemiological studies of musculoskeletal disorders is often resource consuming. Data regarding symptoms are therefore most often collected using self-administered questionnaires instead of medical histories or other personal interviews. Data regarding signs are collected mainly by traditional medical examination. This is time- and resource consuming as each subject has to be seen personally.

By analogy with self-administered questionnaires for symptoms, signs might also be assessed through self-administered examinations. If the subjects observe themselves according to an examination protocol, resources may be saved in epidemiological studies.

Self-administered examinations have been used in clinical medicine, e.g. for signs among patients with rheumatoid arthritis [134]. There are examples where an approach somewhat similar has been used in epidemiological studies, with questions such as "Can you -wash your hair completely (even behind); - lift a full bottle (1 l) with your arm outstretched?" [159]. Data from these kinds of questions can however not be used for "diagnoses" regarding affections of the musculoskeletal system. More specific data are needed, e.g. signs of tenderness at a specific point observed with a specific examination method.

Few epidemiological studies have used specific self-administered examination procedures. In one however, the outcome of a mailed, self-administered examination protocol, regarding 4 different rheumatological signs of hand dysfunction, compared quite fairly to the findings in a subsequent medical examination [41, 167]. The authors concluded that the test was able to identify subjects with hand impairment and could be used as a screening instrument, as only subjects positive in the self-administered test needed clinical investigation in epidemiological studies of hand disability.

No self-administered methods suitable for examination of the neck and upper extremities are however reported. Such methods should therefore be developed and evaluated.

1.9.9 ”Diagnoses” and syndromes

As was shown in section 1.4, proxies and syndromes are used in diagnostics in epidemiological settings. Decision rules and criteria are developed e.g. for neck/shoulder and carpal tunnel ”diagnostics” [135, 222].

Figure 5 illustrates the principal model for ”diagnostics” applied in this thesis. Coexisting symptoms and signs, each fulfilling separate criteria, constitute the main criteria for positive syndromes. Other data, e.g. medical histories, laboratory tests, nerve conduction measurements are also used. Note that criteria for syndromes could include ruling out other ”diagnoses” or syndromes. For example the more specific ”cervical syndrome” rules out the more vague ”neck/shoulder pain syndrome”. Conditions that do not fulfil the criteria for any syndrome will end up as a ”unspecific disorder” or as a symptom ”diagnosis”, e.g. cervicalgia.

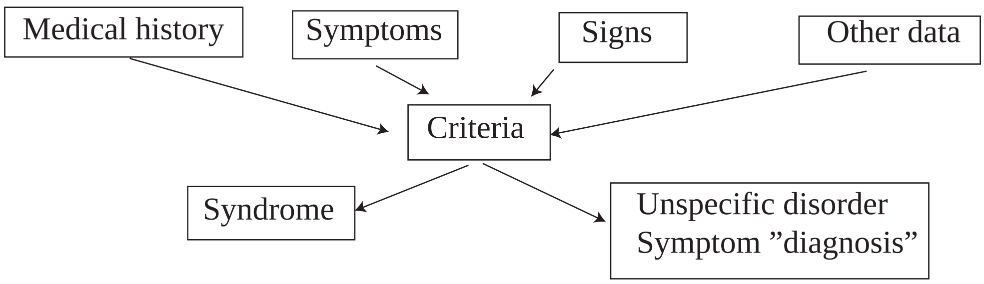


Figure 5. Model for ”diagnostic” procedures in the epidemiological studies in this thesis.

1.10 The starting points for the studies in this thesis

As mentioned above, self-administered assessment of symptoms and signs could save resources in epidemiological studies. Pain drawing is such a method to record the location of symptoms and self-administered examination a method to record signs. Methods for such examination of signs and high resolution pain drawing in the neck and upper-extremities were however not previously available. Development and evaluation of such methods was therefore started. Ratings of exposure and effect variables is another self-administered method used in epidemiological studies. The postulated, and above mentioned, high and low rating behaviour could introduce serious bias in risk estimates based on such ratings. This phenomenon was not previously addressed in research and therefore became one of the topics in the studies constituting this thesis.

Work related disorders have primarily been attributed to load factors on the muscle-tendon systems, but also to compression of the peripheral nerves in the neck and upper extremities. Compression of the brachial plexus was not much studied in the working population. The diagnosis of this compression is based mainly on symptoms and medical examination, where the AER test has been used, but mainly in patient groups. The application of this test to epidemiological studies of the working population with possible mild compression disorders should therefore be tested.

Psychosocial working conditions have been recognised as important risk factors for musculoskeletal disorders. The causal relations are unclear. The validity of the muscle-tension theory as a mediator of these relations could be tested by studying the locations and character of symptoms and signs associated with such conditions.

2. Aims and hypotheses

The over all aim of this thesis was to develop, evaluate and characterise some assessment methods used within epidemiological studies of work-related musculoskeletal disorders in the neck and upper extremities.

The specific aims and hypotheses were:

1 to study associations between work-related exposure factors and the outcome of the abduction external rotation (AER) test (Studies I and II)

2 to study the incidence and prognosis of signs in the AER test and also prognostic factors of and for such signs (Study II)

3 to evaluate self-administered examination of signs in the musculoskeletal system in the neck and upper extremities (Study III)

4 to study the association between self-rated psychosocial work conditions and the characteristics and location of musculoskeletal symptoms, signs and syndromes (Study IV)

Hypotheses were formulated proposing that: symptoms, signs and syndromes associated with stressful psychosocial work conditions are located to central body regions rather than to peripheral regions and that the findings in medical examinations are signs of muscular (soft-tissue) tenderness rather than signs of affections of nerves, joints, muscular insertions or tendons.

5 to study pain drawing characteristics among the general working population with symptoms, signs and syndromes in the neck and shoulder regions, how markings are distributed and how this can be assessed (Study V)

Hypotheses were formulated proposing that: pain drawings among subjects with symptoms of long duration, high intensity, or that are severe would have more separate loci, larger areas and more bilateral and left-right symmetrical distributions.

6 to study whether there is a range of high and low rating behaviour among subjects in epidemiological studies of musculoskeletal disorders and whether there are effects on relative risk estimates when such rating behaviour is stratified for (if both exposure and outcome are rated by the same subject) (Study VI).

3. Subjects and methods

3.1 Subjects and main outlines

Totally 1083 subjects, 431 women and 652 men, participated in one or two of the six studies in this thesis. All belonged to one of three separate epidemiological study groups of active workers. Their total age span was 20-64 years.

Study groups I and II were part of a study about health effects of exposure to vibrating hand-held tools (EPIVIB study). The 186 participants in study I were all men: all available 71 steel-platers at a paper- and pulp-mill machinery factory (mean age 32 years), all 70 assemblers at a truck factory (25 years), and 45 randomly selected office workers at the first factory (37 years). All except the office workers were currently exposed to vibrating hand-held tools, mainly grinders, hammers, nut runners, and screwdrivers. All the participants in study II were men from the paper- and pulp-mill machinery factory. Of the 241 subjects, 151 were examined at the baseline in 1987 (mean age 35 years) and 229 at the follow up in 1992 (40 years), whereof 139 on both occasions. The most common occupations were construction engineer or other office worker, steel plater, turner, assembler. Median seniority was about 7 years. About 40% were exposed to vibrating hand held tools, whereof 65% grinders and 25% hammers.

The study groups in studies III and IV formed part of a methodological project, the major aim of which was to develop and evaluate different methods measuring exposure and effects in epidemiological studies of WRMSD (MUSIC I study). Two specific occupational groups were included, 83 male furniture movers (median age 35 years) and 89 female medical secretaries (41 years), together with 96 male (41 years) and 90 female (43 years) samples from the population aged 20-64 in Stockholm county. Eight of these totally 358 subjects did not participate in study III for technical reasons.

Subjects in studies V and VI were part of a follow-up examination of a cohort from 1970 (REBUS-93 study). Totally 484 subjects were examined (all in the age range 40-59 years), 252 women (mean age 48 years) and 232 men (49 years). The most common occupations among women were nursing, day-care and office work and among men office, manufacturing or technical work.

All studies were approved by the local ethical committees.

3.2 Methods

3.2.1 Symptom recording

Data about symptoms from the musculoskeletal system were collected from all subjects, but were not reported in study III. Studies I, II, and IV used modified versions of the Nordic Questionnaire [110]. "Symptoms" were defined as continuous ache, pain on movement or loading of muscles and joints, or other sensations of discomfort, such as numbness or tingling. Subjects were asked to separately report "current" symptoms and those experienced "ever during the past 12 months" (study IV). Symptoms were separately recorded from the neck, shoulders, elbows-forearms, wrists-hands, thoracic back, lumbar back, hips-thighs, knees or ankles-feet (Figure 4). Studies I and II also recorded day- or night-time numbness in the hands.

Studies V and VI recorded symptoms through a structured medical interview, with similar definitions of symptoms as above.

3.2.2 Medical examination

All subjects were medically examined following similar strict examination protocols, but the results are not used in study VI. The examinations in studies I and II were performed by the same physician (except those of the assemblers). Subjects in studies III and IV were examined by one of eight physicians and in study V by one of two physicians or physiotherapists. The examiner in all studies was blinded to exposure conditions and symptoms.

To enhance the reliability and validity of the examination, special training in examination methods and evaluation was given during practical seminars (with an experienced orthopaedic surgeon as a tutor in studies III-IV). Videorecordings and photographs were used to define standard examination methods, with check-ups during the study progress.

Data on inter-examiner reliability of the medical examination in studies III and IV was fair-good for tests of tenderness, range of joint motion, pain at resisted muscular contraction and nerve compression (κ=0.5-0.6). Inspection had poorer results (κ=0.3) and tests of neuro-motor functions gave very low or uncertain values due to few positive findings.

The totally 43 medical examination items reported in studies I-V are described together with definitions of positive signs in Table 1. The items covered the most common aspects of conventional medical examinations of this kind: *inspection* = sign of deviation in joint alignment, muscular waste etc (items 1, 41); *restricted range of motion* = sign of malfunction mainly of the joints (items 2, 3, 8-10, 37, 39); *pain on resisted muscle-contraction or forced joint motion* = signs mainly of “tendinitis” (items 4, 11-13, 21, 27, 35); *tenderness* = local pressure pain (items 5, 6, 14-16, 20, 22, 24, 34, 36, 38, 40, 42); *tests of sensitivity* = malfunction of peripheral nerve function (items 31-33, 43); *provocation of nerve compression or other stress* (item 7, 17-19, 23, 28-30); *restriction of range of finger flexion* = sign of inflammatory disease (item 26); *joint laxity* = sign of hypermobile joint (item 25).

Table 1 Descriptions and definitions of positive signs in items of the medical examination in studies I-V. (ext.=extension; flex.=flexion; lat.=lateral; max.=maximal; N=Newton; rot.=rotation; vol.=voluntary)

No. Item	Study	Description	Positive sign
1 Shoulder asymmetry	II,III	Inspection of shoulder area	Either shoulder higher or muscle hypo/hypertrophy
2 Neck rotation range	III-V	Max. vol. rot.	<60^o
3 Neck flex./extension range	III-V	Max. vol. flex. and ext.	Either <45^o
4 Neck contraction pain	I	Active shoulder elevation, neck flex. and ext. against resistance	Either contraction painful
5 Neck tenderness	I,III-V	Palpation interspinally and paravertebrally of C2-C7	Distinct tenderness either site
6 Trapezius tenderness	I,III-V	Palpation of trapezius muscle descending parts	Distinct tenderness
7 Neck compression test	I,II,IV,V	Lat. flex. + rot. of neck + axial compression	Pain, numbness or tingling in upper extremity
8 Shoulder abduction range	III,IV	Max. vol. abduction	<180^o
9 Shoulder external rot. range	III,IV	Max. vol. external rotation	<60^o
10 Shoulder internal rot. range	IV	Max. vol. internal rotation	<80^o
11 Shoulder abduction pain	I,III-V	Active abduction 0-90^o against resistance	Contraction painful
12 Shoulder external rotation pain	I,III-V	Active external rot.(0^o abduction, 90^o elbow flex.) against resistance	Contraction painful
13 Shoulder internal rotation pain	I,IV,V	Active internal rot.(0^o abduction, 90^o elbow flex.) against resistance	Contraction painful
14 Rotator cuff tenderness	I,III-V	Palpation of whole rotator cuff	Distinct tenderness
15 Tender point at supraspinous muscle	III	Push finger with 15N on belly of supraspinous muscle	Much more tender than 15 N push on belly of quadriceps femoris, extensor digitorum, tibialis anterior
16 Tender point at trapezius muscle origin	III	Push finger 15 N on origin of trapezius muscle on Th2-3	As No. 15
17 Abduction, external rotation test (AER test)	I-V	Bilateral abduction 90^o+ ext. rot. 90^o+elbow flex. 90^o+ fist clench/release during 1 minute (study III-V) 3 min (I;II)	Numbness, tingling, sharp pain in upper extremities (+neck/ shoulders in I)
18 Upper extr. nerve stretch	II	(Supine) Head contralat. rot. +flex. + shoulder ext. + arm axial traction	Pain, numbness or tingling in upper extremity
19 Supraclavicular compression	II	Push with thumb caudally in supraclavicular fossa	Pain, numbness or tingling in upper extremity
20 Lat. humeral epicondyle tenderness	IV	Palpation of forearm extensor in-sertions on lat. humeral epicondyle	Distinct tenderness
21 Wrist extension pain	III,IV	Active wrist extension against resistance	Contraction painful
22 Frohse´s arc local tenderness	IV	Palpation of Frohse´s arc	Only local tenderness
23 Frohse´s arc radiating pain	IV	Palpation of Frohse´s arc	Deep forearm pain
24 Wrist tenderness	IV	Palpation of wrist joint, extensor and flexor tendons	Distinct tenderness either site
25 Wrist joint laxity	IV	Forced maximal right hand: -thumb abduction -extension	Either of: thumb parallel to forearm finger parallel to forearm
26 Finger flexion deficit	III	Clench fists	Fingers don´t reach palm
27 Finkelstein´s test	IV	Forced wrist ulnar flex.	Distinct radial wrist pain
28 Phalen´s test	I-IV	Forced wrist flexion 90^o during 1 minute	Numbness, tingling or pain in digits I-IV

Table 1 (continued)

No. Item	Study	Description	Positive sign
29 Tinell´s sign, elbow	II	Tap with fingers 2-3 times over median epicondyle	Pain, numbness or tingling in digit V
30 Tinell´s sign, wrist	II,IV	Tap with 2 fingers 3 times over carpal tunnel	Pain, numbness or tingling in digits I-IV
31 Sensitivity, median nerve	II,III	Gentle strokes with finger on tip of digits I-IV	Sensitivity to touch clearly decreased
32 Sensitivity, ulnar nerve	II,III	Gentle strokes with finger on tip of digit V	Sensitivity to touch clearly decreased
33 Sensitivity to vibrations	II	Tuning fork on MCP-joints II-V	Sensitivity clearly decreased
34 Erector spine tenderness	IV	Palpation of erector spine muscles Th1-L5	Distinct tenderness
35 Springing test	IV	Manual sagittal push on each vertebrae Th1-L5	Distinct pain
36 Interspinal tenderness	IV	Palpation interspinally of L1-S1	Distinct tenderness
37 Spine lateral flexion range	IV	Max. vol. lat. flex. of spine with fingertips sliding down the leg	Distance of fingertip slide <17 cm
38 Hip tenderness	IV	Palpation of femoral trochanter major and piriformis muscle	Distinct tenderness either site
39 Hip rotation range	IV	Max. prone forced internal and external rotation of the hip joint	Either internal rot.<35° or external rot. <45°
40 Knee tenderness	IV	Palpation of patella tendon and edges, femoral-tibial joint, lat. and medial insertion of hamstrings	Distinct tenderness either site
41 Hallux valgus	IV	Inspection of toe I	Valgus deviation >15°
42 Foot tenderness	IV	Palpation of Achilles tendon, plantar fascia, metatarso-phallangeal joint I	Distinct tenderness either site
43 Sensitivity leg/foot	IV	Gentle strokes with finger on patella, lat. ankle, lat. edge of foot, metatarsal II-III and toe I	Sensitivity to touch clearly decreased either site

The AER test was carried out as described by Roos - 90° abduction and external rotation and elbow flexion (“hold up position” – Figure 6) together with simultaneous intermittent closing and relaxing of the hands during 3 minutes (1 minute in studies III-V) [174]. Criteria for positive neurological signs in the AER test were: pain, tingling or numbness in the neck or upper extremities. Vascular (cyanosis) and other signs (tiredness, stiffness) were recorded separately, but are not reported here.

In study IV signs in some items were combined to form composite items, e.g. "spine muscle tenderness" (tenderness in the extensor muscles in the neck, back or the descending trapezius), "joint tenderness" (tenderness in muscular insertions, tendons or joints in the upper or lower extremities or the back), "nerve compression" (nerve stress or compression in the spine or upper extremities) (see Study IV for definitions).

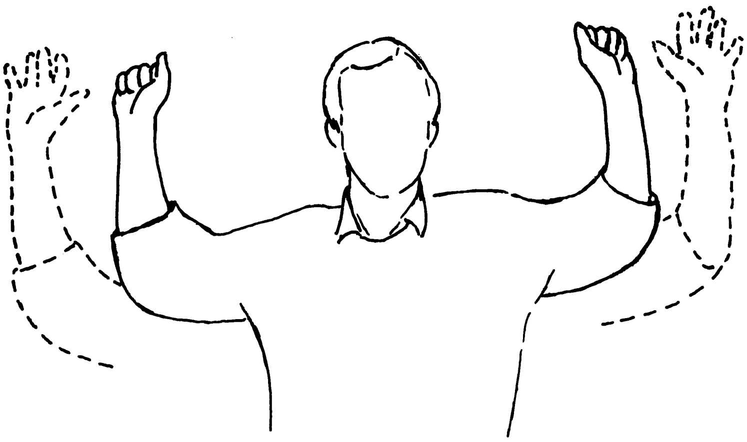


Figure 6. The Abduction External Rotation test.

3.2.3 Syndromes

Studies I, IV and V defined specific syndromes, based on coexisting current symptoms and signs at the medical examination. The minimal criteria for the different syndromes are given in Table 2.

Table 2. Minimal criteria for syndromes in studies I, IV and V. Symptoms (=current ache, pain or other discomfort) had to coexist with medical examination signs. See Table 1 for description of items and definitions of positive signs.

Syndrome	Study	Symptom location	Medical examination signs
Cervical syndrome[A,B]	I,IV,V	Neck—wrist/hand	Neck compression test
Brachial plexus syndrome[A,B]	I,IV,V	Neck—wrist/hand	AER test
Supinator syndrome[B]	IV	Elbow/forearm, wrist/hand	Frohse´s arc radiating pain
Carpal tunnel syndrome[B]	I,IV	Wrist/hand	Phalen´s test or Tinnel´s in study IV
Neck/shoulder pain syndrome	I,IV,V	Neck or shoulders	Neck or trapezius tenderness (or neck contraction pain in study I)
Rotator cuff syndrome[C]	I,IV,V	Shoulder	Rotator cuff tenderness <u>and</u> abduction, internal or external rotation pain or painful arc
Lateral epicondyl pain syndrome[C]	IV	Elbow/forearm	Lateral epicondyl tenderness <u>and</u> wrist extension pain
de Quervain´s syndrome[C]	IV	Wrist/hand	Wrist tenderness <u>and</u> Finkelstein´s test
Lumbar pain syndrome	IV	Lumbar back	Erector spine or interspinal tenderness or springing test painful
Hip pain syndrome[D]	IV	Hip/thigh	Hip tenderness
Knee pain syndrome[D]	IV	Knee	Knee tenderness
Foot pain syndrome[D]	IV	Foot	Foot tenderness

A) In study V combined into “Nerve compression syndrome” = either syndrome positive.
B) In study IV combined into “Upper extremity nerve compression syndrome” = either syndrome positive.
C) In study IV combined into “Upper extremity pain syndrome” = either syndrome positive.
D) In study IV combined into “Lower extremity pain syndrome” = either syndrome positive.

3.2.4 Physical exposure

Subjects in studies I and II completed a questionnaire on occupational physical exposure, giving information about length of current occupation, total and daily exposure to different types of hand-held vibrating tools. Acceleration level for each type of tool was measured. The average 4-hour frequency-weighted acceleration level according to ISO 5349 was 5 m/s^2 among the steel-platers and 1 m/s^2 among the assemblers. The office workers had no occupational exposure to vibrating tools.

Level of physical exposure was assessed in studies III and IV with a questionnaire. An index of exposure was constructed by averaging scores from variables measuring arm and neck positions, handling of tools or heavy loads, repetitive hand/finger movements, or precision work (only study III).

Physical load in study VI was assessed with different rating scales (see Study VI).

3.3 Outcome of the AER test (Study I)

Study I had a cross-sectional design. The subjects answered a questionnaire concerning exposure, current nicotine habits and symptoms, and were medically examined at the study centre, as described above.

Differences were analysed between subjects with signs versus those without signs in the AER test regarding age, seniority and exposure to work with hand-held vibrating tools. Associations were analysed between AER signs and symptoms in the neck or shoulder regions, numbness in the hands, and cervical, neck/shoulder pain, rotator cuff, and carpal tunnel syndromes.

3.4 Prospective aspects of the AER test (Study II)

Study II was a prospective dynamic cohort study with a baseline examination in 1987 and a follow-up in 1992. Symptoms and signs were recorded at both examinations as described above. Baseline data were not available to the examiner at follow-up. Information was collected in 1987 on the following diseases and conditions: diabetes, polyneuropathy, asthma, alcohol and nicotine abuse, obesity, trauma and triggering factors for neck and upper-extremity compression symptoms.

Grip strength was measured with a dynamometer and 2-PD with a ridge aesthesiometer. Temperature-corrected measurements of nerve conduction velocities in the median nerve between digit III-palm, palm-wrist (sensory) and wrist-thenar (motor) were made in both hands.

Sick-leave for disorders in neck and upper extremities during the previous 12 months was recorded at the examination in 1992.

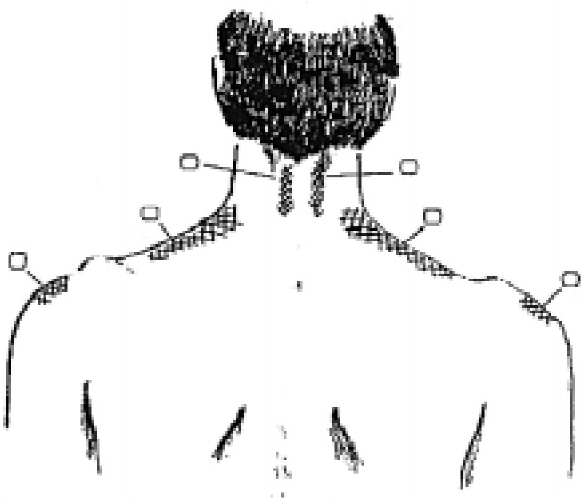
Prevalences of symptom data and of AER and other signs were calculated for both baseline and follow-up examinations. The cumulated incidence of new AER signs in 1992 among those free from AER signs in 1987, the mean duration of signs and the recovery rate were calculated. The predictive associations between exposure conditions at work, symptoms, signs and diseases at baseline and AER signs at follow up were calculated. Also the reverse associations were analysed – the predictive associations between AER signs at baseline and symptoms, signs and sick-leave at follow up. Finally the associations between AER signs and grip strength, 2-PD or nerve conduction velocities were studied.

3.5 Self-administered examination of signs (Study III)

Study III had a cross-sectional design. The subjects were mailed a set of different items for self-administered examination of the musculoskeletal system of the neck and upper extremities. Each item included written instructions and in most cases also illustrations.

The subjects were instructed to record the results as marks on the illustrations, e.g. indicating points of tenderness or range of motion (Figure 7). Each item had the alternatives: “cannot decide” and “cannot perform the test”. Both left and right sides were examined. Items and definitions of positive findings are described in Table 3.

Use your fingers to feel the points on your neck and shoulders that are marked in the figure below. Note if any points are tender, and if so, mark the squares corresponding to those points.



Left		Right	
( )	feel no tenderness	( )	feel no tenderness
( )	cannot decide	( )	cannot decide
( )	cannot perform the test	( )	cannot perform the test

Swing your arms outward and up as far as you can, as shown in the figure. Mark the square on the left and right hand side, which best corresponds to how far you can reach with your arms.

Right	Left	
( )	( )	cannot decide
( )	( )	cannot perform the test

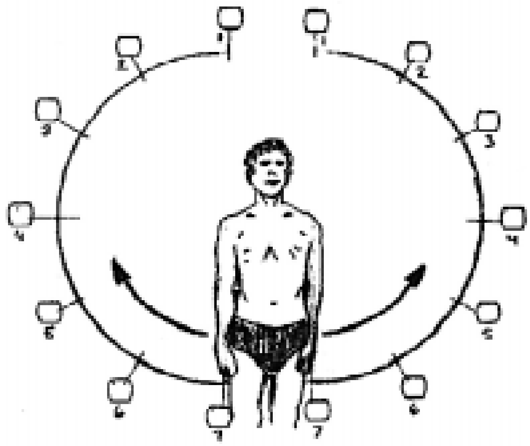


Figure 7. Two items from the self-administered examination in study III. Top: palpation of tenderness in the neck and shoulders. Bottom: range of movement on abduction of the arms.

Table 3 Description and definition of positive findings in items of the self-administered examination in study III. Item numbers are the same as corresponding medical examination item numbers in Table 1.

No. Item	Description	Positive finding
1 Shoulder asymmetry	Inspection in mirror of shoulder area	Either shoulder higher
2 Neck rotation range	Rotate head to maximum and mark angle on illustration (15º intervals)	Markings 0-45º
3 Neck flexion/ extension range	Look up and down to maximum and mark angle on illustration (15º intervals)	Markings 0-30º
5 Neck tenderness	Feel with fingers on area corresponding to mark in illustration of back	Tenderness
6 Trapezius tenderness	As No. 5.	Tenderness
8 Shoulder abduction range	Swing arms laterally/up to maximum and mark angle on illustration (30º intervals)	Markings 0-150º
9 Shoulder external rotation range	Rotate arms outward to maximum and mark angle on illustration (15º intervals)	Markings 0-45º
11 Shoulder abduction pain	Swing arm laterally against resistance e.g. a table as shown in illustration	Pain in shoulder area
12 Shoulder external rotation pain	Rotate arms outward against resistance e.g. a wall as shown in illustration	Pain in shoulder area
14 Rotator cuff tenderness	As No. 5.	Tenderness
15 Tender point in supraspinous muscle	Push with tip of finger on spot corre-sponding to mark in illustration showing belly of supraspinous muscle. Compare sensation to corresponding push on the frontal thigh as illustrated	Much more tender
16 Tender point at trapezius insertion	As No. 15 on trapezius muscle insertion on vertebrae Th 2-3	Much more tender
17 AER test	Abduction, extension, rotation of the arms while slowly closing and opening fists as shown in illustration (1 minute)	Numbness, tingling, pain or fatigue in the upper extremities
21 Wrist extension pain	Extend wrist against the resistance of other hand as shown in illustration	Pain in marked area of lateral elbow
26 Finger flexion deficit	Clench fists	Fingertips do not reach palm
28 Phalen´s test	Flex back of hand against surface for one minute as shown in illustration.	Numbness, tingling or pain in digits I-IV
31 Sensitivity median nerve	Stroke gently with a pencil on tip of digits I-IV	Sensitivity much weaker than other digits
32 Sensitivity ulnar nerve	As No. 31 on tip of digit V	As No. 31

All subjects were medically examined within one-two weeks by one of the physicians, blind to the symptoms and the results of the self-administered examination.

The results for all items and both methods were dichotomised according to the definition of positive findings in Tables 1 and 3. Uni- or bilateral positive findings classified a subject as "positive" and bilateral negative findings as "normal" in prevalence calculations. Using the medical examination as criterion, the sensitivity, specificity and the positive and negative predictive values together with κ-values were calculated as measures of validity for each of the 18 items. Findings had to agree according to laterality to be regarded as congruent. To check whether misclassification of the findings of the self-administered examination was affected by exposure, validities were compared between a group with high exposure and a group with low exposure to occupational strain on the neck and upper extremities as described above.

3.6 Psychosocial conditions and disorder characteristics (Study IV)

Study IV had a cross-sectional design. The subjects rated the following psychosocial work conditions at their current work: "psychological demands", "decision latitude" and "social support". "Job strain" was defined as the ratio between "psychological demands" and "decision latitude". Subjects were categorised for each one of the four psychosocial indices into a "low", "medium" or "high" exposure group by cut-off points approximately at the 30-33:rd and 67-70:th percentiles respectively.

Symptom data from the previous year, medical examination signs, and syndromes covering all body regions, as described above, were used as effect variables. A few medical examination items less likely to be associated with occupational exposure were included as a check of the validity of the results ("shoulder asymmetry", "wrist joint laxity", "hip rotation range" and "hallux valgus").

Associations were analysed between psychosocial conditions and each effect variable controlling for physical load, gender and age. To demonstrate possible linear dose-effect relations, comparisons were made between the high exposure group with the low group and the medium group with the low group respectively. To underline pronounced associations between the psychosocial conditions and effects, specific criteria were established (prevalence of effect variable ≥10% and prevalence ratio ≥1.5 and 95%ci ≥ 1.0 and a dose-effect relation).

3.7 Pain drawing (Study V)

Study V had a cross-sectional design. Those 125 subjects (83 women and 42 men, mean ages=49 years) who reported symptoms in the neck, shoulders or upper back regions at the medical interview were asked to make a pain drawing of the distribution of their symptoms on a body map (Figure 8). The distribution of the pain drawing markings was coded to computer files using a transparent grid of 878 pixels. The number of markings on each pixel was summarised over subjects and plotted topographically. The individual left and right side and total pain drawing areas were summarised. The degree of lateralisation was defined as the ratio of the smallest/largest of the two areas, ranging from 1.0 (=evenly bilateral) to 0.0 (=fully unilateral). Finally, the central-peripheral distribution was calculated as the mean distance from the central line. The congruence with dermatomes C2-C5 and Th2-Th3 was judged using a transparent dermatome map. The separate pain drawing loci were counted. Symmetry regarding left-right distribution and continuation to the arms was judged visually.

Information was obtained about the year of onset of symptoms, total number of days with symptoms or sick-leave, medication and medical care during the past year due to the symptoms. Intensity of ongoing symptoms was rated using a CR10 scale. Subjects with intensive, chronic or severe symptoms were identified (se notes in Study V/Table 1 for criteria). Signs from the neck and shoulder regions were registered during a medical examination (Table 1) and the syndromes “nerve compression”, “neck/shoulder pain”, and “rotator cuff” were defined (Table 2). Both the medical interview and examination were done before the pain drawing.

Associations between pain drawing characteristics and symptom intensity, chronicity and severity and also signs and syndromes were analysed. Differences in pain drawing characteristics between genders, age-groups (40-49 versus 50-59) and high- and low educational level were analysed. Inter-relations between pain drawing characteristics were calculated.

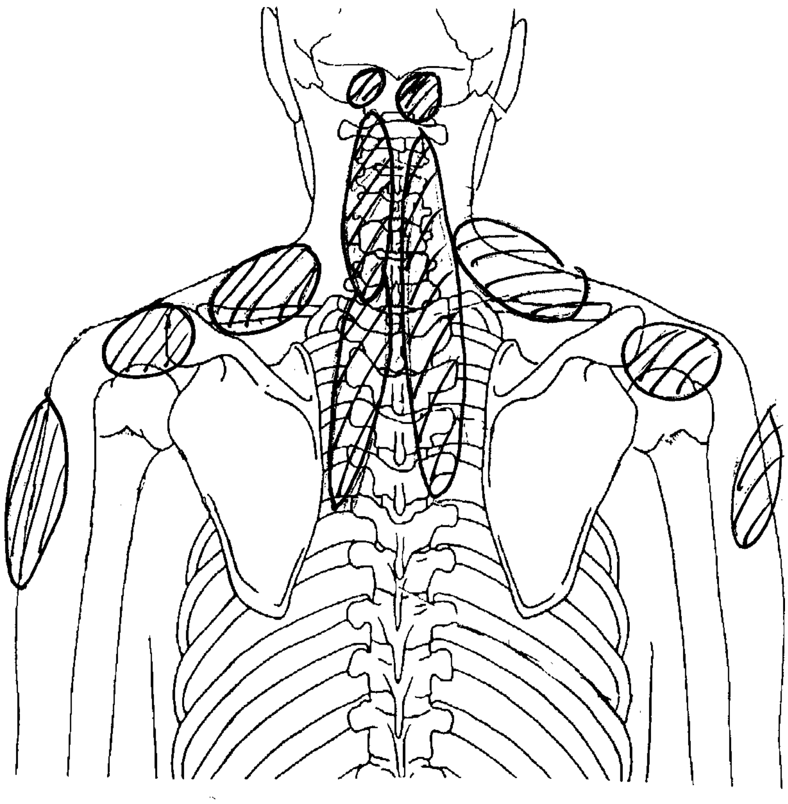


Figure 8. Example of pain drawing. Actual size was 160*165 mm.

3.8 Rating bias (Study VI)

Study VI had a cross-sectional design. Rating behaviour was assessed by asking the subjects to rate the following *fixed* stimuli without information of the “true” values:

- the taste of acidity of a citric acid solution (using a 10 cm VAS scale and a CR10 scale).
- the number of small objects in a box.
- the weight of a box.
- time for the completion of two subparts of a psychomotor test.

Fourteen additional *un-fixed* stimuli were also rated by the subjects using different scales (counted numbers, RPE, CR10, VAS, category scales). These stimuli concerned ratings of their own performance, feelings of exertion and of pain in tests, physical exposure at work (general and of the back or shoulders) and symptoms in the shoulders and low-back regions.

Subjects were not informed about the aim of these ratings.

The postulated existence of a range of high and low rating behaviour was examined by analysing rank-correlations between the different ratings of the fixed stimuli and also between the fixed and un-fixed stimuli. The presence of a range of high and low rating behaviour among the subjects would result in high positive inter-correlations. Rating behaviour was studied in the entire study group but also among subgroups differing in gender, age, educational level and symptoms in shoulders or low back.

Subjects were categorised as "low", "medium" or "high" raters by cut-off points approximately at the 33:rd and 67:th percentile of the average relative rank of ratings of the four fixed stimuli. The potential effects of rating behaviour on relative risk estimates was analysed by comparing crude relative risk estimates with estimates based on stratification for rating behaviour.

3.9 Statistical methods

Most of the reported associations were positive. "Association" in the text is therefore used for "positive association". Un-adjusted or adjusted prevalence ratios (PR) and cumulated incidence rates (CIR) have been calculated as measures of association for discontinuous variables in studies II-V. Study I used the Chi^2 test. Stratification in adjusted analyses was made according to the method described by Mantel-Haenszel [129]. Confidence intervals were test-based [144]. Correlation coefficients have been calculated as measures of associations between continuous variables in study V (product-moment) and VI (rank).

A multiple logistic regression analysis was undertaken in studies I and II using the AER test outcome as dependent variable.

Tests of differences between continuous variables used Students t-test in studies I and II.

All confidence intervals were calculated at the 95% level (95% ci). Reported p-values were two-tailed.

4. Results

4.1 Outcome and prospective aspects of the AER test (Studies I and II)

Prevalences of positive AER signs varied between 31% among the platers, 16% among white-collar workers and 6% among assemblers in 1987 (Study I). The cumulated incidence of AER signs between 1987-92 was estimated to 1.7/100 person-years, the recovery rate to 9.4/100 case-years, and the mean duration of AER signs to 17.7 years. The majority, 70% of the subjects, never showed any AER signs.

There was an expected high association between AER signs in 1987 and 1992 (PR= 6.2 95% ci=3.3-12.). Numbness in the hands, positive signs during provocation of nerve compression or other stress tests of the upper extremity nerves, a decreased sensitivity to vibrations or to touch on the finger-tips, or asymmetric height of the shoulders in 1987 were also strongly associated with both prevalent and incident AER signs 5 years later (Table 4).

Seniority in current work was clearly associated with prospective AER signs. Exposure to work with vibrating hand-held tools was higher among subjects with AER signs and was associated with both prevalent and incident AER signs 5 years later (Table 4) (Study I/Table III).

No substantial associations were noted regarding nicotine or alcohol abuse. Among medical conditions recorded in 1987, asthma, but not obesity or polyneuropathy were associated with prevalent AER signs in 1992[3]. Previous trauma to the neck or shoulder regions, but not to the arms or hands, was associated with AER signs. Reports of triggering factors for neck or upper-extremity compression symptoms were strongly associated with AER signs (Table 4).

The multiple regression analyses confirmed the results from the bivariate analyses. Constitutional factors, previous trauma, medical and exposure conditions were independent risk factors for prevalent AER signs (Study I/p 220; Study II/Table III).

AER signs in 1987 were associated with a higher frequency of symptoms in the shoulders and arms both prevalent and incident 5 years later. Strong associations were also seen with prevalent and incident numbness in the hands (Study II/Table IV). Positive AER signs in 1987 predicted sick-leave due to disorders in the neck and upper extremities in 1992 (PR=1.7-10.0 in different regions).

The sensory nerve conduction velocity in the median nerve on both hands was lower, i.e. indicating a decreased function, among subjects with signs at the 1992 AER test (Study II/Tables V-VI). A small decrease in the sensory nerve conduction velocity between the palm and the wrist in the right hand was seen during 1987-1992 among subjects who became AER-positive during that period. A decrease was also recorded among subjects with persisting signs on both occasions. Those who lost the signs from 1987 or did not react with signs either in 1987 or in 1992 had less substantial changes.

Grip strength in 1992 was about 5% lower among those with a 1992 AER sign than among those without. The 2-PD values from 1992 was higher, i.e. more pathological, among those with an AER sign in 1992 than among those without.

[3] Only two subjects had diabetes, which was therefore excluded from further analysis.

Table 4 Symptoms, signs and conditions in 1987 predictive of AER signs 5 years later. Prevalence ratios (PR) and cumulated incidence ratios (CIR) with 95% confidence intervals (95% ci) and positive predictive values (PPV) for signs during the AER test in 1992 between subjects with specific symptoms, signs or conditions in 1987 compared to those without. PR among all subjects (Prevalent; N=137) and CIR among subgroup of subjects without signs at 1987 AER test (Incident; N =105). n=number of subjects with specified symptom, sign or condition 1987.

	Prevalent AER-signs 1992				Incident AER-signs 1987-92			
	n	PR	95% ci	PPV	n	CIR	95% ci	PPV
Symptoms 1987								
Neck-scapula	23	2.72	1.33-5.52	0.39	15	1.93	0.42-8.81	0.13
Shoulders-upper arm	19	1.88	0.83-4.25	0.32	8	0	-	-
Elbow-forearm	20	2.80	1.34-5.85	0.40	10	0	-	-
Wrist-hand-fingers	23	3.58	1.77-7.22	0.43	12	1.06	0.14-7.99	0.08
Sum neck-upper extr.	55	3.05	1.48-6.29	0.31	35	1.15	0.29-4.56	0.09
Numbness in hands	39	5.65	2.91-11.0	0.46	22	7.55	2.44-23.3	0.27
Signs 1987								
Neck compression test	5	3.44	1.24-9.56	0.60	1	0	-	-
Upper extr. nerve stretch test	5	3.44	1.24-9.56	0.60	3	4.25	0.68-26.6	0.33
Supraclavicular compression	7	3.38	1.37-8.35	0.57	1	0	-	-
Tinell´s test-elbow/ulnaris	9	4.28	2.00-9.09	0.67	3	4.25	0.68-26.6	0.33
Tinell´s test-wrist/medianus	18	4.85	2.57-9.15	0.61	6	8.25	2.71-25.1	0.50
Phalen´s test	17	2.12	0.95-4.74	0.35	10	2.71	0.64-11.6	0.20
Either nerve compression test	31	4.66	2.46-8.83	0.48	13	3.54	1.02-12.3	0.23
Sensitivity test of fingers	11	3.44	1.59-7.45	0.55	5	2.50	0.36-17.2	0.20
Vibration test of fingers	4	4.34	1.60-11.7	0.75	1	13.0	2.79-60.6	-
Shoulder asymmetry	15	1.94	0.82-4.60	0.33	11	2.44	0.57-10.5	0.18
Conditions 1987								
Age≥36 years	66	1.47	0.73-2.95	0.23	45	1.07	0.30-3.77	0.09
Blue-collar work	80	1.49	0.70-3.17	0.22	61	2.52	0.59-10.8	0.11
Seniority at work[1]	67	2.80	1.32-5.91	0.28	49	9.14	1.77-47.2	0.16
Daily vibration exposure[2]	71	2.03	0.97-4.23	0.25	52	3.43	0.83-14.2	0.13
Vibration exposure≥6 years	63	2.94	1.38-6.25	0.29	45	2.62	0.73-9.44	0.13
High vibration dose[3]	57	2.84	1.54-5.25	0.28	26	6.08	1.89-19.5	0.23
Nicotine use	75	1.32	0.65-2.69	0.21	55	1.82	0.49-6.75	0.11
Alcohol abuse[4]	10	1.03	0.28-3.79	0.20	8	1.47	0.20-10.7	0.13
Obesity[5]	10	0.53	0.09-3.17	-	8	0	-	-
Asthma	10	3.02	1.31-6.99	0.50	4	0	-	-
Polyneuropathy	9	1.16	0.32-4.24	0.22	5	0	-	-
Trauma to neck/shoulders	4	2.77	0.80-9.66	0.50	0	-	-	-
Trauma to arms/hands	22	0.68	0.23-2.00	0.14	17	0.65	0.09-4.69	-
Trigger factors[6]	7	4.42	1.98-9.89	0.71	1	0	-	

1) Current work>7 years
2) Work with vibrating hand-held tools >15 minutes/day
3) Cumulated acceleration dose during lifetime above 75:th percentile (>27 774 hours* m/s^2)
4) Pathological CDT-RIA, S-Alat and γ-GT
5) Body mass index (weight kg/length m^2)≥ 28
6) Pain, numbness or paraesthesia in neck or upper extremities at work above shoulder level, specific sleeping position, carrying of heavy objects etc.

4.2 Self-administered examination of signs (Study III)

The prevalences of positive findings in the self-administered examination varied between 2 and 47% among the different items (Study III/Table 2). The highest values were noted on items measuring tenderness and on the AER test. The corresponding prevalences in the medical examination varied between 1 and 20% with a similar distribution among the items. Ratios between prevalences from the self-administered examination and the medical varied between 1.2 and 14 (median 3.5) with 13 of 18 confidence intervals above 1.0.

The sensitivity values of the items in the self-administered test varied between zero and high (Study III/Table 3). The highest values (0.55-1.0) were noted for items of tenderness, finger flexion deficit, and the AER test. The specificity values were moderate to high (0.63-0.99), being lowest for tests of tenderness and for the AER test. The positive predictive values varied from 0 to 0.36 and the negative from 0.92 to 1.0. Finally, κ varied from 0 to 0.50 being highest for tenderness and finger flexion deficit.

Results from the comparison of the high-exposure group with the low-exposure group showed a similar pattern. The item-specific differences in validity values between the two groups were mostly small and all 95% confidence intervals included zero, except in 3 cases.

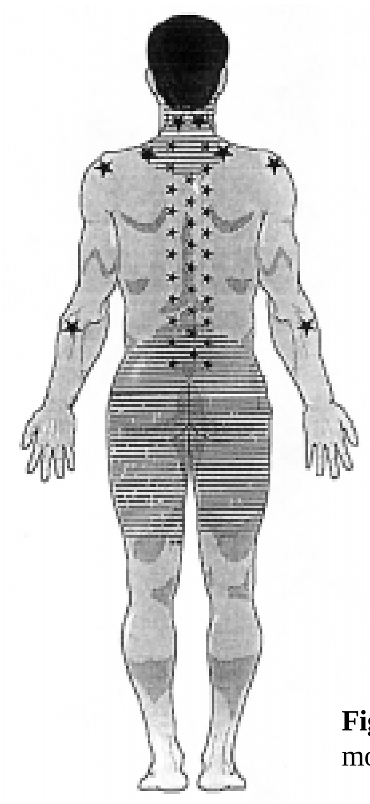
On average 23% of the subjects failed to mark a positive or a negative finding on the different items. This included 15% who returned blank examination sets, 4% no answers on specific items, 3% answers "Cannot decide" and 1% "Cannot perform the test". The highest frequencies of missing data were noted on tender points (Nos. 15 and 16). The results of the medical examination did not, however, differ substantially in a systematic way between this "missing data" group and the others. Ratios between prevalences ("missing data" group/others) of positive findings at the medical examination varied between 0.0 and 5.8 among the different items (median 1.2). The proportion of subjects with high occupational physical exposure was about the same in the "missing data" group and the others. Ratios varied from 1.1-1.4 (median 1.3).

4.3 Psychosocial conditions and disorder characteristics (Study IV)

The variation in self-rated psychosocial exposure was high, judging from the standard deviations in the total group and means and ranges in the high-, medium- and low-exposure groups. Females, the low age group and those with high physical load tended to report more unfavourable psychosocial work conditions.

The most common symptoms were found from the neck, shoulder and lumbar back regions. Pronounced associations with the psychosocial variables were seen regarding the neck, back and hip regions (Figure 9)(Study IV/Table 2). Somewhat weaker associations were seen between social support and symptoms from many body regions except shoulders, which showed no substantial association with any of the exposure variables. The index "decision latitude" had very few associations with any of the effect variables.

The most frequent and pronounced associations to signs were noted from the neck, shoulder, arm and back regions (Figure 9)(Study IV/Table 3). All pronounced associations were to signs of tenderness, mainly in muscles (soft tissues). Scattered associations, however mostly not fulfilling the criteria for pronounced association, were also seen. Among the summary variables, only "spine muscle tenderness" showed pronounced associations, mainly with psychological demands and job strain. No substantial



associations were noted with the check variables “shoulder asymmetry”, “wrist joint laxity”, “hip rotation range” or “hallux valgus”.

Associations to co-existing symptoms and signs were seen only in the neck and low back, as described by the syndromes “neck/shoulder pain syndrome” and “lumbar pain syndrome” (Table 5).

4.4 Pain drawing (Study V)

In the medical interview 109 subjects reported neck symptoms, 110 shoulder and 45 upper-back, with median duration of 8.1 years and mean intensity of present pain about 3.5 on the CR10 scale. There was a considerable overlap, so that only ten subjects reported symptoms

Figure 9. Location of symptoms (stripes) and signs (stars) with the most pronounced associations with high self-rated psychosocial load.

Table 5. Prevalences of syndromes based on the co-existence of questionnaire-based present symptoms and signs at medical examination of 358 subjects of mixed gender and occupations. Prevalence Rate Ratios (PR) with 95% test-based confidence intervals (ci) among subjects with *high* exposure versus subjects with *low* (High/low) and subjects with *medium* exposure versus subjects with *low* (Medium/low) to 4 variables of self-rated psychosocial work conditions. PR based on Mantel-Haenszel calculations on data stratified by gender, two age-groups and low/ high physical load at work. # indicates conditions fulfilling the criteria: $PR_{High/low}$ ≥1.5, $ci_{High/low}$ >1.0, $PR_{Medium/low}$ >1.0 and $PR_{High/low}$ ≥$PR_{Medium/low}$.

	Psychosocial exposure variable							
	Psychol. demands		Decision latitude		Social support		Job strain	
No. Item (prevalence %)	PR	ci	PR	ci	PR	ci	PR	ci
1 Neck/shoulder pain syndrome (9.9%)								
High/low	1.7	0.65-4.6	1.3	0.50-3.4	2.7#	1.1-6.7	2.3	0.83-6.6
Medium/low	0.70	0.23-2.1	1.5	0.57-3.9	1.0	0.37-3.0	1.7	0.51-6.0
2 Upper extremity pain syndrome (3.1%)								
High/low	1.8	0.20-16	3.0	0.50-18	..[A]	..	..[A]	..
Medium/low	2.5	0.24-27	1.3	0.14-11	..[A]	..	..[A]	..
3 Upper extremity nerve compression syndrome (7.2%)								
High/low	1.0	0.33-3.0	1.0	0.31-3.4	2.4	0.66-8.8	1.7	0.55-5.1
Medium/low	0.99	0.30-3.3	0.59	0.18-1.9	1.7	0.50-6.2	1.2	0.43-3.7
4 Lumbar pain syndrome (11%)								
High/low	2.8	0.88-9.0	1.7	0.65-4.3	3.7#	1.0-13	2.2	0.86-5.7
Medium/low	1.3	0.38-4.3	1.2	0.41-3.5	2.2	0.68-7.1	1.3	0.40-4.0
5 Lower extremity pain syndrome (8.2%)								
High/low	0.59	0.16-2.1	0.65	0.29-1.4	1.8	0.49-6.8	0.42	0.13-1.4
Medium/low	0.87	0.32-2.4	0.46	0.20-1.1	0.83	0.29-2.3	0.92	0.33-2.6

A) Calculations not possible due to zero cell frequencies.

solely from the neck, eleven solely from the shoulders and none from the upper-back. The distributions of the markings in pain drawings among subjects reporting symptoms from either region were consequently similar to that of the total group (Figure 10). Distributions among subjects reporting solely either neck or shoulder symptoms were however unique (Figure 11a-b).

On average two separate loci were marked on the pain drawings (range 1-10), covering a total area of 96 pixels (range=8-332), and corresponding to approximately 3.5% of the total rear body surface area or about the area of both palms (StudyV/Table 1). The

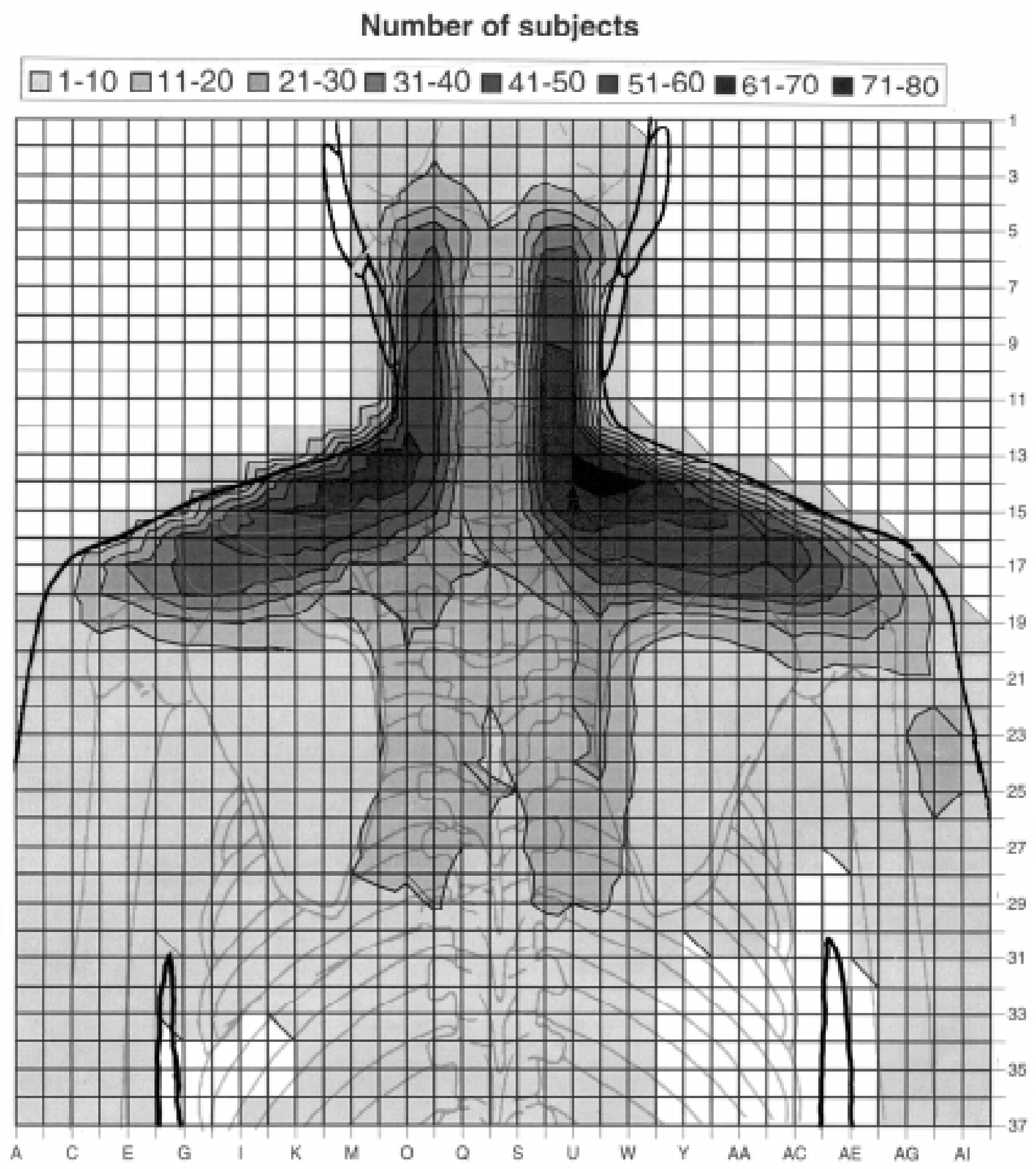
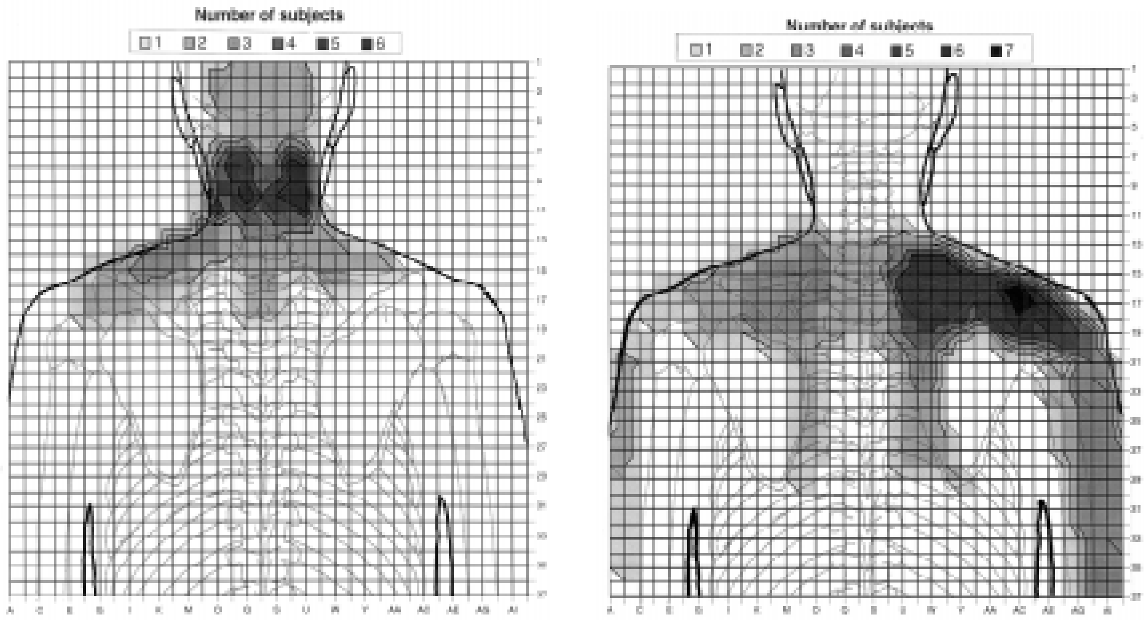


Figure 10. Topographical diagram of aggregated pain drawings. Darker shades indicates higher frequency of markings. Subjects with symptoms in the neck, shoulders or upper back. n=125.



A **B**

Figure 11. Topographical diagram of aggregated pain drawings. Darker shading indicates higher frequency of markings. A) Subjects with symptoms solely in the neck. n=10. B) Subjects with symptoms solely in the shoulders. n=11.

average right side area was 50 pixels and left side 46 pixels. A difference of up to 4 pixels (1 cm^2) between right and left sides was seen in 25 drawings and 32 were fully unilateral (16 each side). The mean distance from the central axis was about 6 pixels (=distance from spine to inferior angle of scapula). Half of the pain drawings were judged to be symmetrical. Somewhat fewer were congruent with dermatomes, mainly the C3 and C4, (43 left and 44 right). Even fewer indicated symptom continuation to arm-hand regions (13 left and 16 right). Women made pain drawings with more separate loci than men did (2.5 versus 1.7; 95%ci of difference=0.17-1.34), larger areas (106 versus 77 pixels; 95%ci=3.70-53.3) and more bilateral (ratio=0.59 versus 0.42; 95%ci=0.02-0.31), central (distance=5.9 versus 6.7 pixels; 95%ci=-1.89-0.27) and symmetric distribution (55 versus 38%; 95%ci=0-36). No significant differences were associated with age or educational level.

No substantial or systematic associations could be seen between the pain drawing characteristics and reports of different symptom qualities – ache, pain, tenderness or stiffness.

Subjects with chronic symptoms made pain drawings with more separate loci and larger areas, and those with severe symptoms made pain drawings with larger areas than subjects with symptoms of shorter duration or less severity (Study V/Table 1). There was a tendency for subjects reporting more intense ache or pain in either region to make pain drawings with more separate symptom locations or larger areas. These associations differed between the body regions. Intense *neck* symptoms were associated with more separate symptom locations of bilateral distribution. Intense *shoulder* symptoms were associated with larger unilateral distributed areas far from central axis and with continuation into the arms, and intense *upper-back* symptoms with small areas close to central axis.

Subjects who were found to be tender in the neck and trapezius regions at the medical examination made pain drawings with larger areas, more separate loci and more bilateral, central and symmetrical distribution (Study V/Table 2). Associations with other signs were less pronounced.

The associations between syndromes and pain drawing characteristics were weak. Subjects with the “neck/shoulder pain syndrome” (n=65) tended to make more centrally located pain drawings with less indications of pain radiation to upper extremities. Subjects with the “rotator cuff syndrome” (n=13), on the other hand, tended to make more asymmetrical and peripherally distributed pain drawings. No clear patterns were seen among subjects with “nerve compression syndrome” (n=32).

The inter-correlations between the different continuous pain drawing variables were low or modest. The maximum was noted between number of separate loci and the ratio of smallest/largest body side area (r_{xy}=0.42). There was also, as expected, a positive association between the categorical variable “symmetry” and the ratio of smallest/largest areas (PR=14.).

4.5 Rating bias (Study VI)

Inter-individual variation and range of ratings showed good distributions allowing studies of high and low rating behaviour (Study VI/Table 1). Most variables followed a normal distribution curve.

Correlations among the ratings of fixed stimuli were all close to zero and both positive and negative (Study VI/Table 2). Correlations between ratings of fixed stimuli and un-fixed stimuli, exposure and outcome variables, respectively, were also mostly close to zero and both positive and negative. Correlations between ratings using the same scale were also low (VAS, RPE and CR10 respectively). The correlation between the VAS and CR10 ratings of acidity was high (r=0.84) as was the correlation between the 30 and 60 seconds time estimations (r=0.70). No curve-linear relations were observed in plots of variable pairs.

Correlations between the ratings of fixed or un-fixed stimuli within each subgroup (gender, age, education, case-status) were also close to zero. No *systematic* differences were observed in the mean ratings of fixed or un-fixed stimuli between the different subgroups. Gender was connected to the most substantial *specific* differences. Mean ratings of fixed stimuli by gender (females/males) were: acidity 41.6/42.7 mm (diff=-1.08; 95% ci=-7.78 to 5.62); count 81.4/69.4 pieces (diff=12.1; 95% ci=-0.88 to 25.0); weight 4.73/5.28 kg (diff=-0.55; 95% ci=-1.26 to 0.15); time 51.5/44.7 sec (diff=6.79; 95% ci=1.68 to 11.9).

Prevalence ratios for intensive symptoms and the selected exposures differed between genders. The stratified PR-values were therefore calculated separately for males and females (Study VI/Table 3). No substantial effects of adjustment for high, medium and low rating behaviour were noted among either group, even when other cut-off points on the symptom-scale were used for case-definition.

5. Discussion

The aim of this thesis was to develop, evaluate and characterise assessment methods used within epidemiological studies of WRMSD in the neck and upper extremities. Special attention was paid to self-administered methods, relations to psychosocial risk factors and signs of nerve compression. Different occupational groups and general population samples participated in the studies. Both cross-sectional and prospective study-designs were used. The quality of symptom assessments, medical examinations and "diagnostics" were enhanced via special training procedures, strict protocols and predetermined criteria.

It was found that self-administered examination of signs is generally not valid with the possible exception for examination of tenderness. It was also found that poor validity of self-ratings in epidemiological studies is probably not caused by high and low rating behaviour among the subjects. Muscular and soft tissue tenderness and symptoms in central body regions were found to be associated with self rated unfavourable psychosocial conditions. Further, tenderness in the neck and trapezius muscle, and intense, chronic or severe symptoms, were associated with large painful areas as shown in self-administered pain drawings of the neck and shoulder regions. Finally, it was found that compression of the brachial plexus, seen as signs at the AER test, was reversible and related to many factors, constitutional, disease, trauma, and work exposure.

5.1 Signs of nerve compression

This thesis found an annual incidence of new neurological AER signs of approximately 2/100 person-years among mixed industrial and office workers. Further, the recovery rate was estimated to about 9/100 case-years and the mean duration of neurological AER signs to about 18 years. Compression of the brachial plexus is thus a long-lasting, but not irreversible, disease as judged by the AER test. This thesis has also shown that subjects with AER signs are at greater risk of suffering neck- and upper-extremity disorders with future sick leave.

5.1.1 Possible mechanisms

The major pathogenic mechanism causing traumatisation of the brachial plexus is local mechanical compression of the neuronal bundle between skeletal or otherwise tight tissues, e.g. between the clavicle and first rib or between the scalene muscles [182]. Potentially compressive anomalies, such as fibrous bands or cervical ribs, in these regions are over-represented among patients suffering from compression neuropathies but are also seen among a general population [94, 173]. Mechanical traction/stretching during joint movements, e.g. in the case of tethered nerve bundles can have harmful effects on the peripheral nerves similar to compression [97]. Friction between the neuronal bundle and surrounding tissues during tendon or joint movements is another possible cause. Single neck traumata, mainly due to car or work-related accidents, iterative traumata due to repetitive neck and upper extremity movements or awkward working postures and persisting traumata due to anatomical (mal-) formations are possible trauma sources.

As shown in section 1.5.2, these traumatisations are believed to cause intraneural ischaemia and oedema with further compression and successive dysfunction. Through interference with the forward and retrograde axonal transport mechanism, a local compression can cause dysfunction along the whole length of the nerve, both proximally and distally.

The theory of “double or multiple crush” postulates that traumatisation of a peripheral nerve, e.g. due to compression, makes the nerve axon more vulnerable to further compression along its total distribution from the spine to the peripheral endpoint [34, 128, 215]. There are several narrow spaces where axons passing the brachial plexus can be compressed (naming the compressed part of the nerve):

-the intervertebral foramina (spinal roots and dorsal root ganglia)
-anomalies in the neck - cervical rib, fibrous bands (brachial plexus)
-the scalene muscles (brachial plexus)
-the costo clavicular space (brachial plexus)
-the minor pectoral muscle (brachial plexus)
-sulcus ulnaris and cubital tunnel (ulnar nerve)
-supinator muscle (deep branch of radial nerve)
-pronator teres muscle (median nerve)
-carpal tunnel (median nerve)
-Guyon´s canal (ulnar nerve).

This theory applied to the upper extremities could thus explain the associations found in this thesis between signs of nerve compression in the brachial plexus and signs of nerve compression in the intervertebral foramina in the cervical spine, the cubital tunnel in the elbows, and the carpal tunnel at the wrists. These associations were found both for prevalent and incident signs from both baseline and follow-up examinations in studies I and II. Such multiple compressions have been described among patients suffering from TOS [244].

Further support was found in this thesis for the “double or multiple crush” theory in that subjects with AER signs had lower nerve conduction velocities in the hand regions, mainly the wrists. Moreover, subjects with persisting or new AER signs in 1992 compared to 1987 tended to have an approximately 10% decrease in velocity in the right wrist. Those who lost their AER signs during this period showed a slight normalisation and those with no signs showed the least change in conduction velocities. Previous studies of patients suffering from compression of the brachial plexus have found similar impaired nerve conduction findings in severe cases [158].

Upper-extremity nerve compression can lead to a rise in the perception thresholds of the vibration and skin-touch receptors in the hands. Further, long-lasting or severe compression can reduce the muscle strength and the innervation density in the fingers [154]. These phenomena were confirmed in this thesis, as the AER signs were strongly associated with numbness in the hands and with decreased sensitivity to touch and vibration of the fingers. A slight decrease in grip strength and 2-PD discriminating capacity in the fingers was also noted among subjects with AER signs.

5.1.2 Relations to work and other risk factors

Both work-related factors and those related to constitution, disease and trauma were found to be risk factors for AER signs in this thesis.

Study II revealed seniority at work, but not age, as the most prominent risk factor for incident AER signs. Exposure to work conditions where hand-held vibrating tools are used was associated with AER signs in both the cross-sectional and the prospective studies. Such exposure has been found to be associated with impaired nerve conduction in the brachial plexus [96]. The association between work with hand-held vibrating tools and neurological AER signs is not straightforward, however. Traumatisation is possible through vibrations or jerks, power grips, unhealthy working postures or movements associated with such work [102].

Psychosocial work conditions were not found to be associated with AER signs or any other sign of nerve compression or affection in the neck or upper extremities. This is in accordance with the hypotheses in study IV.

Associations with other possible causes or triggers of compression of the brachial plexus were verified in this study, such as working or sleeping with arms cranial to shoulder level, shoulder asymmetry, and trauma to the neck (as opposed to trauma to the arms or hands) [182]. Neck trauma, such as whiplash injury, is associated with fibrosis of the scalene muscles, which is a possible cause of brachial plexus compression [183]. Associations with obesity, polyneuropathy, or alcohol abuse were not, however, verified in this study [128, 149]. Asthma was found to be a strong risk factor for prevalent AER-signs. This has not previously been reported. A plausible causative connection is the fact that the scalene and minor pectoral muscles are accessory respiratory muscles. Extensive use of these muscles due to breathing difficulties, as in asthma, might make them hypertrophied and thus cause compression of the brachial plexus. Another explanation might be a hyper-inflated thorax cage associated with asthma. This could hypothetically narrow the costoclavicular space and thus cause brachial plexus compression.

More studies are indicated on compression of the brachial plexus with special attention to possible interactions between individual predisposition (e.g. constitution, trauma, disease) and harmful occupational exposure (e.g. postures and movements in the neck and upper extremities and manual handling). There may be specific combinations that should be prevented.

5.1.3 Evaluation of the AER test and its usability

Assuming the earlier mentioned multiple causality of nerve injury and the validity of the “double and multiple crush” theory, it can be concluded that evaluation of nerve injury anywhere in the neck and upper extremities should include the brachial plexus. The AER test is a recommended test of compression of the brachial plexus [153, 171]. With no information in this thesis about true brachial plexus compression among the subjects, very little can be concluded about the validity of the AER test as a test of brachial compression disease. There were only indirect indications that the AER test provokes compression of the brachial plexus – its associations with biologically plausible risk factors and with symptoms and signs indicative of neck and upper-extremity nerve traumatisation. The multiple associations with signs of other upper-extremity nerve compressions indicate that the test is unspecific as regards the location of the compression. However, assuming the validity of the “double and multiple crush” theory, no test of nerve compression can be specific regarding the location. Finally, the outcome of the AER test predicts future disorders in the neck and upper extremities. Almost every other subject with an AER sign at baseline examination had new symptoms or signs in the neck or upper extremities five years later.

The AER test is easy to perform. Modifications have been suggested, such as shortening its duration from 3 minutes to 1 minute, manual pressure in the supra-clavicular fossa during the test, omitting elbow flexion or hand gripping [153, Study III, IV]. Other suggestions concern using different methods for recording upper-extremity nerve dysfunction, e.g. electrodiagnostic measurements, vibration- or skin-sensitivity thresholds, during or immediately after AER testing [27, 153]. Documentation on the reliability and validity of the AER test or its modifications is however sparse. Inter-examiner reliability of a 1-minute version of the test was found to be good in one study (κ=0.62) [8]. Future studies should address these methodological issues. The validity of the “double and multiple” crush theory and its implications to the prevention, evaluation and rehabilitation of neck- and upper extremity nerve entrapment diseases should also be further studied.

The AER test is not suited for self-administered examination, according to the results of study III. Self-administered examination over-estimated the prevalence of signs about 3.5 times with a fair sensitivity and specificity (0.7) but very poor PPV and κ (=0.14). Also the Phalen´s and other tests of nerve function had poor validity in the self-administered examination. No substantial or specific characteristics patterns in the pain drawings in study V were noted among subjects with signs of nerve compression in the neck or during the AER test.

To summarise, the AER test is a supplementary tool in epidemiology and occupational health settings for evaluating work-related neck and upper-extremity nerve compression disorders, and has the possibility to be further improved.

5.2 Self-administered examination of signs

5.2.1 Poor validity of self-administered examination

In this thesis a self-administered examination test of signs in the neck and upper extremities was developed and evaluated. Except for self-administered hand tests, few other such tests for epidemiological use have been described [41].

The prevalences of positive outcomes were much higher in the self-administered examination than in the medical examination. The low PPV in our study imply that only few of the positive findings in the self-administered examination were confirmed in the medical examination. On the other hand, the majority of the negative findings were confirmed in the medical examination. Conversely, only a moderate proportion of the signs in the medical examination was registered in the self-administered test.

The agreements above that of chance, as measured by κ, were mostly "slight" (0-0.20) [112]. Only one item, “finger flexion deficit” reached "moderate" κ (=0.50). It is noteworthy that items requiring only inspection or judgement of motion range showed low validity. Items judging tenderness had somewhat better validity. This could possibly be explained by the fact that during assessment of tenderness the physician, too, has to rely on the response from the subject.

In the earlier-mentioned study of self-administered examination of hand function, the sensitivity can be calculated from data given in the article to 0.69, specificity to 0.97, positive and negative predictive values to 0.91 and the κ to 0.62. The item "finger flexion deficit" in the present thesis resembles one of the three items in that study and had similar validity values.

The findings in this thesis can be compared to those of studies where two examiners examine the same subject. As mentioned earlier, the agreement between the examining physicians in this study was clearly higher than that reported here regarding assessment of tenderness and joint function (κ=0.5-0.6). Only inspection had poor values (κ=0.3). A study of a physician and a physiotherapist examining the same neck patients found κ=0.24 for palpation of tenderness in the neck and κ=0.42-0.44 in the shoulders [235]. This can be compared with κ=0.34 (neck) and κ=0.27 (trapezius) in this thesis. Different tests of sensitivity and range of joint movement yielded κ around 0.5 compared to 0-0.2 in this thesis.

Professionals such as physicians or physiotherapists are more familiar with the examination methods, and have wider frames of reference and more congruent criteria of normality. In studies of agreement using clinical patients and/or with limitations to certain regions of the body, there also is the possibility that the experts are more observant of relevant aspects than here, where a selection from the working population is examined and where one of the examiners (the physician) has to examine the whole body without focusing on any suspected region or disorder and is blind to possible symptoms. As was shown earlier, validity studies using patients tend to overestimate the sensitivity values. Other possible reasons for the poor validity of the self-administered examination could be e.g. the lack of control over prior conditions and over the execution of the examinations The inter-examiner reliability of the medical examination was not perfect either, as was shown above. Each of the above mentioned factors could contribute to the lack of agreement between the two examination methods.

5.2.2 The usability of self-administered examination

The overestimation of the prevalences of signs renders the present version of self-administered examination unsuitable as a replacement for a medical examination in *descriptive* epidemiological studies. The mostly moderate values of specificity and sensitivity imply that the present version cannot *replace* a medical examination for identifying cases with signs in *analytical* studies. Finally, the modest sensitivity values make the present version unsuitable for use in *clinical* applications as too many patients with signs would be missed.

A potential use of self-administered examination is as a *screening method* in *analytical epidemiological* studies of the relation between exposure and signs of musculoskeletal *tenderness*. Tenderness is a common and important sign of MSD and is included in many diagnostic criteria, e.g. “tendinitis” or “neck/shoulder pain syndrome”. The validity values of items measuring tenderness in the present version of the test were mostly acceptable. It was shown in section 1.8.2 that low sensitivity does not introduce serious bias to risk estimates in analytical studies, as long as the prevalence of the sign is not high. High specificity is needed in order to avoid bias, however. The classification of disorders, e.g. "neck/shoulder pain syndrome", would thus proceed in two steps. Primarily all subjects would complete a self-administered test of tenderness of the neck and descending trapezius muscles. Secondly, only those subjects reporting positive findings would need further examination by professionals for definite diagnostic appraisal. Used in this manner the process of identification of cases resembles the method called "serial testing" in clinical epidemiology [53]. The moderate specificity of the self-administered tests of tenderness could thus be perfected in the subsequent professional examination of the screened subjects. The modest sensitivity of the present items of tenderness could be an obstacle to their use as a screening method in situations where the incidence or prevalence of the signs is high. No serious exposure-related bias was observed in this study, indicating that the misclassification was not exposure-dependent.

The following example illustrates the reduction in the need for professional examination resources if self-administered examination of tenderness is used as a screening tool. If the true prevalence of tenderness is 15% (e.g. tenderness in the neck or shoulders) and the sensitivity and specificity of the self-administered examination is 0.80 (comparable to the values found in this thesis), then the number of subjects needed to be examined for final appraisal of the presence of the sign would be reduced by about 70%. Signs with lower prevalences will show even higher reductions. Further improvements in validity, mainly the positive predictive value, of the screening test will also further reduce the need for professional examinations.

5.2.3 Possible improvements of validity

The results suggest methods of improving the validity of self-administered examination such as this. There should be fewer items in a test protocol. Separate items covering a specific phenomenon could be combined into an index. Only those who exceed a criterion value on the index would then proceed to final professional examination. The definitions of positive findings should be more clear, unambiguous and easy to follow. This would perhaps lower the number of missing data and increase the validity. The design of a self-administered examination should also stress its explicitness and simplicity in order to secure compliance.

5.3 Psychosocial conditions and disorder characteristics

5.3.1 Support for the hypotheses

The results from this part of the thesis supported the hypotheses about location and character of MSD associated with poor psychosocial working conditions. The most pronounced and consistent associations were found between high mental demands or low social support and co-existing symptoms and signs of muscular (soft-tissue) tenderness in the central body regions (neck and low back), most clearly described by the "neck/shoulder pain" and "lumbar pain" syndromes. The findings from earlier studies were confirmed regarding associations with symptoms from the neck and back regions [84, 92, 116, 120, 148, 223, 228]. Theorell and co-workers also found associations between demand-control-support variables and symptoms from the back, neck or shoulder regions but not from the other joints [205]. The results in this thesis disagree with the conclusions from some other studies declaring "a general musculoskeletal sensitivity to mental stress" [116, 148].

In congruence with the hypotheses, few associations were noted in the more peripheral regions of the body, i.e. the upper or lower extremities. The exception is the pronounced association with local tenderness at Frohse´s arc. Frohse´s arc was palpated as a test of compression of the radial nerve. This test affects, besides the radial nerve, also the wrist and finger extensors and the supinator muscle. Local tenderness was quite frequent and is possibly a sign of muscle (soft-tissue) tenderness. Symptoms from the arms were associated with poor psychosocial work conditions among production workers but not office workers in one of the few other studies covering the arm region [229]. No correction was however made for physical load in that cross-sectional study. Psychogenic muscle tensions, recorded by electromyography, have also been reported from flexors in passive forearms during experimentally induced stress [200]. Studies regarding the legs or feet have reported diverging associations [10, 229].

The sum of all nerve-tests showed no pronounced association with psychosocial variables, which is in accordance with the hypotheses. No other studies have been found reporting results from tests of nerve affections in connection with psychosocial factors, except one reporting positive associations with sciatica [148].

The findings of associations with tenderness in several locations could tentatively be explained by decreased pain thresholds among the subjects. A study of a randomised subgroup of these subjects, on the contrary, showed higher pain thresholds among subjects reporting high mental demands [207].

This thesis, in addition to a few other studies, reports associations between self-reported psychosocial work conditions and - not only symptoms but also - signs from the musculoskeletal system [116]. Studying signs makes effects of possible negative affectivity or exposure-dependent bias in the disorder-assessment less probable than studying symptoms only. Bias from high and low rating behaviour was in this thesis found to be a less probable explanation to such relations between self-rated psychosocial conditions and self-reports of symptoms (Study VI).

Prospective associations have been demonstrated between self-rated psychosocial work conditions and successive symptoms and signs of MSD [116]. This is an important finding in the search for possible causal relations between psychosocial work conditions and MSD. More research in this field is needed, however.

There are also other theories linking poor psychosocial work conditions to MSD, besides the theory of muscular tensions described in section 1.7.2. These theories postulate an increased "alertness" to symptoms such as pain among exposed subjects, or a limited ability to cope with stressful situations and alarming signals from the body. They also point to the possibility of a shift towards a more catabolic state as a result of stressful psychosocial conditions in conjunction with an increased arousal state and a release of catabolic hormones. Uneasiness, depression or pain during the night could further decrease the healing and anabolic processes during sleep [204]. These postulated linking mechanisms could hypothetically further augment a derangement of (tension) overloaded muscle tissues and make the subject more vulnerable to further load. They could also increase the awareness of pain and malfunction in these muscles. These other theories could thus be seen as complementary to the theory of muscle tensions as a mediating mechanism.

5.3.2 Implications

According to the present results, psychosocial work conditions have pronounced associations to symptoms and specific signs in central body regions. If data regarding WRMSD (effect measures) are lumped together from different body regions and different signs, true associations could be hidden as this would have the same effect as non-dependent misclassification of the effect measure, with attenuation of the risk estimates as a consequence [178].

5.4 Pain drawing

5.4.1 Pain drawing distribution

In the majority of the pain drawings, neck, shoulder or upper-back symptoms were most frequently located to the neck-shoulder angles on each side of the cervical spine. There was no demarcation between the neck and shoulder regions. Instead they continued into each other and also to less frequent locations in the upper back. The co-variation of symptoms between the neck and shoulder regions, as found in this and many other studies, is therefore understandable. On the other hand, the markings made by the groups with isolated either neck or shoulder symptoms indicated separate symptom locations, central neck and (right) shoulder joint, respectively. No specific upper-back symptom region was found. Many questionnaires used in occupational health surveillance of e.g. musculoskeletal disorders and in epidemiological studies use rear-view body diagrams to define the delimitation between different regions [29, 110, 127, 133, 199]. The findings in this thesis suggest that such body diagrams should bilaterally separate a neck section and a more peripheral shoulder (joint) +upper arm section from a central shoulder section, in order to enhance specificity (Figure 12).

The topographical picture of the aggregated symptom distribution was bilateral and symmetrical. The picture resembles the anatomical location of the descending parts of the trapezius muscles. Tenderness in the trapezius, but not other signs, showed also the most substantial and consistent associations with the pain drawing characteristics. Similar

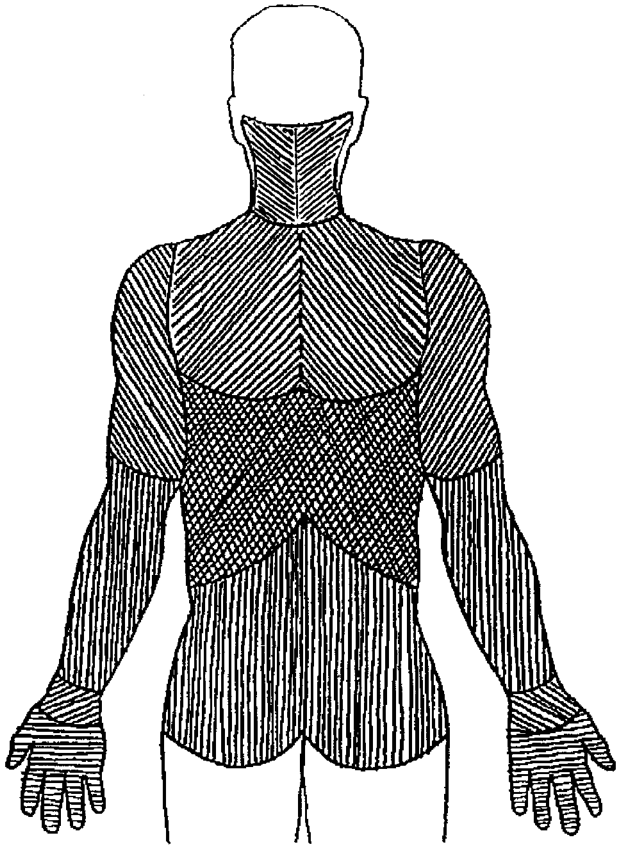


Figure 12. Example of body diagram with separation of the neck, central and peripheral shoulder-upper arm regions. Other regions are not studied here, why their delimitations are only tentatively suggested.

findings of an association between pain drawing (area) and signs of cervical myalgia, but not other signs from medical or x-ray examinations, have recently been reported [246].

The low frequency of symptom location to the very central parts is noteworthy. It can reflect a ”silent” area. The distribution of the symptom-affected areas was even and the average right side area was only 1 cm^2 (8%) larger than the left side area. Strictly unilateral pain drawings were seen among only 25%, and the more or less predominate area was about equally common in the right and left body sides. The frequent symmetry among the individual pain drawings, and specially among women (55% versus 38% among men) is also noteworthy. The causal relations in this left-right evenness and symmetry are unclear. Bilateral symptom-generating mechanisms are one possibility. There is in this thesis less support for a contralateral spread of primarily unilateral processes, as there were no strong positive associations between symmetrical or bilateral pain drawings and symptom intensity or duration, as was proposed in the hypotheses. Symmetry aspects were noted by one of the pioneers of pain drawings, H. Palmer, who stated that symmetry ”..is almost diagnostic of a functional nervous disorder, or the functional superstructure which the patient may have built up around organic lesion” [157]. This cannot be verified here, in absence of relevant data about the subjects’ mental state.

5.4.2 Size of the pain drawing area

The area covered by the pain drawings and the number of separate loci were associated with chronic, severe and (but less strongly) with intense symptoms and with signs of tenderness in the neck and shoulder region on medical examination. Associations between pain drawing area and symptom duration, intensity and severity have been reported [106, 209, 246]. This supports the hypothesis of a spreading of intensive or long-lasting nociceptive pain, at least ipsilateraly. There are also other possible explanations, such as referred nociceptive pain, radiating neurogenic pain, and pain from deeply located structures, e.g. periost and ligaments [50, 100]. It is also noteworthy that women drew larger pain areas than men did. Large pain drawing areas have been reported to be associated with "idiopathic" low-back pain [2]. Whether this also relates to the neck-shoulder region has yet to be studied.

5.4.3 Other pain drawing characteristics

The other pain drawing characteristics, uni/bilateral or central/peripheral distribution, had less substantial or consistent associations to the symptoms or signs studied. Pain drawings resembling the distribution of the dermatomes showed no clear association to nerve-compression signs and syndromes. As the distal parts of the upper extremities, crucial for dermatomal diagnostics, were not included in the pain drawing, no conclusions about the validity of this characteristic can be drawn. The proximal distributions of the C2-Th3 dermatomes differ substantially between different published dermatome charts, indicating large individual or methodological variations [51, 83, 140].

5.4.4 Evaluation of pain drawings

Several previous studies have reported quantification of pain drawing characteristics, mainly the size of the area [106, 132, 209, 246]. However, most studies of the area aspect used much lower resolution in the quantification of the area, typically 45 pixels for the whole body front and rear views, compared to 878 pixels in this study (restricted to the rear upper half of the body excluding the arms). Low resolution leads to overestimation of the true area [21]. Studies of other characteristics, such as number of separate pain loci, lateralisation, central/peripheral or symmetrical distribution, are few [131, 208]. No reports have been found about the spatial distribution of aggregated pain drawings, like the topographical figures in this study. Furthermore, most previously studied groups were patients with more or less chronic pain from the low-back region. The present study reports pain-drawing results from the neck-shoulder region among the general working population, and includes possible subgroup, e.g. gender, differences. The use of pain drawings not only in occupational health work but also in epidemiological studies is suggested. The use of computer-based scanning techniques would simplify such high-resolution data entry, as used in this study. It would also be possible to further elaborate the software that handles this input for final calculations of the pain drawing characteristics, such as area and spatial distribution. Even left-right symmetry could be quantified. This would augment the reliability of the quantification of pain drawing characteristics.

One of the aims in this thesis was to develop and use different methods to characterise and quantify pain drawings. The mostly weak interrelations between the variables used indicate that they give unique information about the pain drawings. Symmetry was, as expected, highly associated with bilateral distribution (high ratio smallest/largest area). Among characteristics used in this study, the total area and number of separate loci showed most pronounced and consistent associations with symptoms and signs. The usefulness of the pain-drawing characteristics studied identifying subjects with different possible diagnoses (here studied as the “neck/shoulder pain”, “rotator cuff”, or “nerve compression” syndromes) was limited. The lack of information about clinical diagnoses and the non-inclusion of the arms and hands in the pain drawings made the conclusions of such specific pain drawing “patterns” not definite in this study. Pain drawings among subjects with solitary distinct diagnoses, including nociceptive, neurogenic and referred pain, but also among those with “non-organic” pain affecting the neck and upper extremities should therefore be analysed with the present methods or modifications thereof. Further, the results should also be replicated in studies including younger subjects and disorders of more recent or acute onset in order to enhance the generalisability. Pain drawings associated with malignancies, acute trauma or other serious (non-work related) disorders have not been studied here.

5.5 Rating bias

5.5.1 No high and low rating bias

In study VI concerning bias from high and low rating behaviour in epidemiological studies, different sensorial modalities and cognitive demands were chosen for the rating tasks - estimation of taste, weight, quantity, time lapse, exertion, pain and frequency. Different rating methods were also chosen - free ratings and Likert, RPE, CR10 and VAS scales. No signs of a range of high and low rating behaviour were found among the subjects. Low correlations were also seen between ratings where the same type of rating scales were used. This further supports the absence of high and low rating behaviour. This is a welcome result as the consequences of the reverse would have been cumbersome. The presence of such rating behaviour would have implied that relative risk estimates from epidemiological studies where both exposure and outcome measures were based on subjective ratings by the same subject could be uncontrollably biased, typically being overestimated. Special adjusting procedures would have to be considered in such cases. One such would be to measure and adjust for individual high or low rating behaviour, using the same methods as in this study. Another would be to design the rating scales balancing the effects of such rating behaviour. An alternative would be to refrain from using risk estimates based on subjective ratings of both exposure and outcomes[4].

5.5.2 Sources of rating bias

Many other rating behaviours and personality traits, reported to bias ratings or judgements, have been studied in the science of psychometrics, e.g. "response set or style", "social desirability", "self-deceptors", "halo effects", and "yeasayers and naysaysers" [30, 32, 85, 89]. Biases in rating behaviour can be divided into those associated with the content of the rated item ("response set") and those without association to the content ("response style") [175]. Examples of the former are e.g. "social desirability" or "negative or positive affectivity" (see below) and of the latter "extreme response bias". Except for range or spread of numerics used in ratings [16, 47, 65, 66, 93, 203], few consistent "response style" biases have been demonstrated [65, 175]. The hypothetical "high and low rating behaviour" could be considered as a "response style" and therefore our negative results are consistent with these previous findings. It has been stated that the more ambiguous the rating or judging task is, the more probable is the introduction of different rating bias [162, 175]. The rating-tasks in our study varied in ambiguity. Some tasks were quite self-evident and easy, like rating of

[4] There are, however, also other reasons not to rely solely on subjective ratings of both exposure and effects [108].

number of curl ups or dumbbell lifts, but other were more ambiguous and difficult, like ratings of acidity or pain. No systematic associations were, however, noted regarding ambiguity of the rating task and rating behaviour.

5.5.3 Bias from negative affectivity and other emotional loading

The hypothesis about bias from high and low rating behaviour resembles the findings associated with "negative affectivity". Negative affectivity has been defined as “a mood-dispositional dimension that reflects pervasive individual differences in the experience of negative emotion and self-concept” [224]. Many studies have shown that different perceived stressors are associated with perceived symptoms, distress and health [35, 42, 160, 185, 245]. Negative affectivity has been shown to correlate to both the perceived stressors and to the strain [147, 177, 225]. A bias (overestimation) from negative affectivity to measures of association between stressful exposure and different outcomes has been argued, but also disputed [17, 18, 26, 177]. Similar biasing effects have been associated with "positive affectivity", i.e. “an ability to cope unusually well with stressful situations and to have a sense of coherence or dispositional optimism” [177].

Possible effects of negative or positive affectivity were not included or controlled for in our study. The rated stimuli in our study are not to be considered as stressful or emotionally loaded. All stimuli, with the exception of the pain ratings, can be considered as "neutral" stimuli, without affective or emotional connotations. Ratings of pain in the PPT test showed only minimal correlations with ratings of present pain in the shoulders or low back, indicating that these ratings were not substantially affected by some common factor such as negative or positive affectivity. Thresholds for pain, but not for pure sensation, have in other studies, however, been found to be sensitive to personal characteristics, e.g. "self-deceptiveness" [89].

5.5.4 Bias from differential misclassification

The postulated bias from high and low rating behaviour resembles the effects of differential misclassification. Both have the same consequence of uncontrollable bias in relative risk estimates [151]. Both sources of bias are due to an artefact of irrelevant associations between the exposure and outcome measures.

5.5.5 Rating bias in subgroups

Gender differences have been demonstrated regarding mean values in use of Likert scales, in validity of ratings of energy demands at present work or in giving numeric values to verbal expressions, like "very often" [65, 80, 234]. Differences in rating behaviour between age and socio-economic groups have earlier been described and could hypothetically have been expected in this study due to differences in educational level and supposed familiarity with judgements, evaluations and numbers [65]. Likewise differences between subjects suffering from pain and those free from pain (cases versus non-cases) could hypothetically have been expected due to a possible higher "arousal level" or "alertness" for stimuli. Subdividing the subjects did not however reveal any subgroup characterised by systematically higher or lower ratings or a range in such rating behaviour. The results so far do therefore not support the idea that observed differences in validity of ratings among different subgroups in epidemiological studies are explained by differences in high and low rating behaviour.

5.6 General comments

5.6.1 The central role of symptoms

A state of pain or other symptoms together with malfunctioning in work or leisure time activities, are perhaps the most common manifestations of many MSD. Symptoms inflict somatic and mental pain and agony. Symptoms are the main phenomenon that urges the subject to take action, e.g. seek medical care, apply for sick-leave, modify work exposure or personal capacity. Symptoms have great negative impact on the wellbeing of the subject and indirectly, also on the economy and efficacy of the company and the community. Symptom data are therefore central in studies of MSD, both descriptive and analytical.

Etiological and clinical studies, on the other hand, often use diagnoses as effect measures. Many diagnoses have symptoms as one of their main criteria, however, e.g. carpal tunnel disease. If only symptom data is available in such studies, and as long as this estimation about the "true" disease state is unbiased, the influence of this inprecise diagnostics can be predicted (=underestimation of "true" associations in analytical studies – see section 1.8.2). If the specificity of the symptom data is insufficient, symptom data could be used as a screening instrument. Other more precise but more resource-consuming methods, e.g. medical examination, could then be applied to the symptomatic subjects to further increase the specificity of the combined assessment process. The optimal combinations of different assessment methods, parameters and criteria for positive "diagnoses" are however unknown. More research in this field is therefore indicated.

Methods for symptom assessment could be further elaborated. Computer based questionnaires for self-administered presentation and entry of data is one possibility. The questions could be arranged in a tree-structure where the answer on one question decides what questions should follow. This could make the assessment procedure more specific and also avoid unnecessary questions which makes the questionnaire lengthy and otherwise decreases motivation and accuracy.

In many cases of MSD there are no manifestations in known observable signs, only symptoms. It should however be noted, that the present methods of sign-findings are crude in epidemiological studies. The methods are most often non-invasive and rely on what can be observed "externally" with the eyes, hands, knowledge, and experience of the examiner. It is not far-fetched to suppose that there are diseases with signs that we are not (yet?) able to observe.

5.6.2 The role of self-reports and principles for optimal assessment procedures

Self-reports of sick-leave and other medical history data and of symptoms have fair – good (test-retest) reliability, as shown in the introductory sections (κ=0.6-0.9). Validity, on the other hand, diverges, using previous records or examination of signs as "true" values. Specificity is mainly good (>0.9) but sensitivity is typically poorer (0.4-0.8). Self-reported data, e.g. symptoms, can be influenced by different non-disease related factors in the subject, e.g. perception, cognition, motivation, and coping ability. Exposure-dependent misclassification is a feared complication. This has perhaps been the major hindrance to sole reliance on symptoms as effect data in etiological studies of MSD. Other more independent information about the disorder is therefore necessary for valid conclusions about causal relations. Such data could be signs at medical examination, (laboratory) tests, observations or tests of functional status etc. Most of these assessment methods are resource-consuming, however, and therefore not suitable for epidemiological studies where data are collected solely for the purpose of the study. This fact was the starting point for the study of self-administered examination of signs in this thesis. Unfortunately the results showed that self-administered examination of signs is non-valid, if the results of a traditional medical examination are used as a criterion for “true” signs. Self rated health or work ability has, on the other hand, been reported to have good prognostic validity in other studies [12, 87]. The development of self-administered or otherwise resource-saving but valid methods suitable for epidemiological studies or health surveillance should continue.

Similar problems exist regarding assessment of critical exposure. Self-reports are used in order to save resources. Such self-reports have often questionable validity and both disorder-dependent and non-dependent misclassification is a problem [238, 240]. The combination of self-reported exposure and effect data in risk estimations is prone to bias for several possible reasons [107, 177]. One would be high and low rating behaviour. The results from studies in this thesis did not support this source of bias, however.

There is no simple solution to this resource - validity conflict in the choice of assessment methods in epidemiological research. A suggestion for assessment of disorders in etiological and analytical studies of MSD in populations or occupational groups could however be as follows. Data about the disorder state could be combined from different data sources, both self-reported and external. One obvious source is self-reported symptom data. To these data other self-reported information could be added that do not depend primarily on the perceptions and evaluations of bodily signals such as pain. Disorder-specific derangement of functional abilities or decreased productivity and quality, sleep disturbance due to pain etc are examples. An external source of information could be medical examination signs, tests or other clinical data. As suggested above, such clinical data could be assessed in subgroups of subjects, screened or otherwise selected. Another external source could be registers at company or local health care units or health insurance institutions (visits, diagnoses, sick-leave etc.). These are all data at individual level. Aggregated data could be added, such as prevalence or incidence of relevant medical or related conditions in the occupational group of interest. Productivity and quality data could also be used. National or company survey data are useful.

The same combination of different data sources and levels - individual (self-reported and external) and aggregated - is also useful in assessment of exposure data. Exposure and effect data at the same level may then be combined in risk calculations. Exposure, effect and risk estimates on different levels should agree. If not, the discrepancies should be carefully analysed. Discrepancies could also be of interest, e.g. sub-groups of symptomatic subjects without signs or critical exposure could point at increased vulnerability or lack of coping ability. The combination of effect data at different levels can minimise the negative effects of the weakness of each individual method and benefit from their specific qualities [108].

A guiding principle for the choice of specific assessment methods, or combinations thereof, is high sensitivity of the procedure for ruling *out* and high specificity for ruling *in* a specific disease (see section 1.8.2).

5.6.3 Evaluation of assessment methods

A couple of remarks are in order concerning the evaluation of assessment methods as such data were presented in the introductory section. Evaluation studies based on patient groups will tend to overestimate the sensitivity of the method and studies based on non-disordered subjects selected from healthy volunteers will overestimate the specificity of the method [20]. This means that methods evaluated on clinical patient groups are expected to be somewhat less sensitive when applied to epidemiological studies of working populations. Evaluation of assessment methods should therefore be based on samples of subjects similar to the population where the methods are expected to be used.

Turning to methods evaluated on clinical patient groups, the positive predictive value is positively affected by the prevalence of the disorder. This means that the positive predictive value of a test evaluated on a clinical patient group will be lower when applied in an epidemiological study of the working population, where the prevalence of the disorder is lower. The κ-value is also influenced by the prevalence of the disorder, being highest for prevalences around 50% and decreasing for more frequent or less frequent disorders. For these reasons quality measures of assessment methods should be standardised and reported at the same prevalence value, e.g. 10% or as likelihood ratios [20].

To facilitate comparisons in this thesis prevalences and composition of study groups are reported in addition to validity values of assessment methods.

It was shown in section 1.8.2 that high specificity in the estimation of disorder is important in *risk-analytical* studies of non-frequent disorders. In health *surveillance* and in *descriptive* epidemiological studies of prevalence or incidence of disorders, both sensitivity and specificity are important for preventing bias to results. In *clinical* settings, but also in epidemiology, high sensitivity (of a negative test) is specially important when ruling *out* a disorder and high specificity (of a positive test) when ruling *in* a disorder [6]. There are thus different (opposing) requirements on the tests when making distinctions between competing diagnoses. The disorder that is ruled in, e.g. “neck/shoulder pain syndrome” should be assessed with high specificity and disorders that are to be ruled out, e.g. “cervical rizopathia” should be assessed with high sensitivity.

5.6.4 Possibilities of early effects

The detection of “early effects” is of specific interest to preventive work. Early effects could make the subject or the authority in charge of health and wellbeing among personnel observant of a potential health hazard before it becomes manifest. Preventive action could be taken, e.g. exposure modification, change in working technique, increase of individual capacity. Reliable and valid measures of early effects, subjective or observable, could be a valuable tool in active work place health surveillance [176]. There is however generally very little knowledge about the progression of WRMSD from early/intermediate effects to a chronic and perhaps disabling state with sickness pension. There is also little knowledge about possible early warning symptoms or signs of such disorders and how this could be assessed. More research in this field is therefore indicated.

5.7 Sources of error and limitations

5.7.1 Measurement errors

Symptom data. All studies, except III, reported symptom data. Studies I, II, and IV assessed symptoms with questionnaires similar to the Nordic Questionnaire. The reliability and validity of this instrument have been reported as good, but not perfect (see section 1.9.2). It does not substantially differ between regions of the body [110, 155]. Studies V and VI recorded symptoms through a strictly structured medical interview. There are no data about its reliability or validity. Medical interviews are, however, sometimes used as “golden standards” for validity studies of questionnaires.

Signs. All studies, except VI, reported signs from medical examinations according to methods described in section 3.2.2. Examinations in studies I-II and III-V used similar quality assurance methods, protocols and criteria for positive signs. The reliability of examinations in studies III and IV was studied and found to be mainly fair-good, as described in the methods section. It did not substantially differ between examination categories, except inspection that had poor reliability. Reliability of the AER test was reported to be good in the only study found to address this issue (κ=0.6). The reliability (and validity) of the AER test as a tool in the diagnostics of compression of the brachial plexus should be further studied.

There were thus no indications that bias was selective regarding body regions or structures. The main results of study IV were therefore probably not affected by differences in quality of data from different regions of the body, neither symptom or signs of different types.

The medical examinations of the subjects in studies I and II were performed by the same examiner, except the assemblers in study I. Remaining differences in the examination procedures and criteria for positive signs could at least partly explain the low prevalence of AER signs among the assemblers compared to the others.

Other assessment methods. The reliability of the self-administered examination procedure in study III was not investigated and no other studies are reported. It could however be postulated that all subjects were “novices” in using these methods, and for this reason the reliability of their examinations could be questioned. The validity was poor, according to the results of study III. Due to low prevalences of positive findings in many items, the point estimates of sensitivity and positive predictive values must be regarded as highly uncertain, as shown by the wide confidence intervals.

Internal consistency and test-retest reliability were shown to be fairly good regarding the indices "mental demands" and "social suport", but not "decision latitute" in study IV, which can partly explain the consistent lack of associations with the latter index [206]. The subjects in study IV were chosen from different occupations in order to obtain variation in both physical and psychosocial exposure; furniture movers, secretaries, and population samples. Analyses stratifying for subgroup showed the same main pattern as the results above, indicating that subject-category did not act as a serious confounder.

The reliability of the pain drawing process and the coding was not studied. As mentioned earlier, previous studies have reported good stability and also reliable coding/evaluation of pain drawing areas. The reliability of the quantitative measures in study V relies on the reliability of the coding of the distribution of the pain drawings, which probably was similar to that in other mentioned studies where transparent grids and matrices were used. The reliability of the visual judgements (e.g. symmetry) is, however, less known.

Study VI does not provide data about the reliability of the ratings. It is, however, unlikely that lack of reliability could attenuate hypothetically substantial intercorrelations to those observed very low, both positive and negative, intercorrelations in that study. The (expected) findings of the relatively high correlations when the same stimulus situation was rated twice (acidity with CR10 and VAS scales; time of 30 and 60 seconds tests) further supported this. The spread in ratings between subjects was sufficient to examine the correlations between the rated variables. There was no evidence of non-linearity in the associations among the variables. Thus neither of these factors can explain the findings of the low intercorrelations. Non-parametric statistics (Spearman-Brown correlation coefficients) were used in this study as some of the rating scales only were on ordinal level. Corresponding Pearson correlation coefficients did not, however, differ much from the present results.

5.7.2 Sampling and data loss errors

Study group I+II. Inclusion of subjects to the cross-sectional study I was without dropouts. Bias was possible however as potential subjects who might be on sick-pension or had left the company or profession due to disorders related to compression of the brachial plexus were not entered to the study. Such a “healthy worker” effect could lead to an underestimation of the prevalence and incidence of the studied symptoms and signs.

Fourteen subjects were lost to follow-up in study II, mostly because the subject had left the company. Prevalences of AER signs at baseline examination did not significantly differ between this and the study group.

Study group III+IV. Totally 507 subjects were approached and 358 participated (71%). No substantial differences in health status were found between the study group and a subgroup of 34 subjects from the dropouts (telephone interview and health register notes).

The volume of missing data in study III, mainly because of dropouts, was substantial but not selective regarding the results of the medical examination or occupational physical exposure. Reasons for this high rate of dropouts could be the large number of items in the mailed test protocol (totally 31) with addition of other mailed questionnaires. High rate of missing data or dropouts limit the usefulness of a self-administered examination as this threatens the validity and the power of the study.

Study group V+VI. The participation rate at follow-up was 62**%** of the eligible subjects from the baseline examination in 1970. About 60% of the lost-to-follow-up group were interviewed by phone. There were no significant differences in neck symptoms at baseline or neck and upper extremity disorders during the past year between the study group and the lost-to-follow up group.

Some of the rating variables in study VI were only rated by the last 175 subjects called for examination. Nothing indicates that this restriction of data had any relation to possible high and low rating behaviour.

5.7.3 Limits to generalisability

All subjects in this thesis came from different occupational groups or population samples. The subjects represented the most common physical and psychosocial work exposure conditions among the general working population.

One limitation to the generalisability of the results was the absence of female subjects in studies about the AER test. Disorders due to compression of the brachial plexus are reported to be more common among women [115]. Few women were, however, available in the typically male occupations in studies I and II. Compression of the brachial plexus and the usability of the AER test should therefore be further studied with priority to female subjects and occupations.

Another limitation was the restriction of age range (40-59 years) among subjects in the studies of pain drawings and rating behaviour. The study of rating behaviour was also limited to neutral and non-affective stimuli. There are still possibilities of specific rating behaviours related to emotionally loaded stimuli.

5.7.4 Specific sources of error or limitations

Steady state in study II. The cumulative annual incidence, the recovery rate and the mean duration of AER signs in study II, were calculated assuming a steady-state condition and no transient cases in the study group. The prevalences in the whole group of 137 subjects did, however, change from 32 to 26, indicating a slight disruption of the assumed steady state. Using the mean prevalence value from the two examinations=29/137 yields a “corrected” cumulative incidence of about 2.2/100 person-years, a recovery rate of about 8.2/100 case-years, and a mean duration of approximately 12 years. It is, however, not known whether there were transient cases, with durations shorter than the five years between the two examinations. The calculated mean duration of the AER sign, 12-17 years, suggests that there was no substantial number of such cases. The calculated cumulative incidence and the recovery rate must in any case be regarded as minimum estimations and the calculated mean duration as a maximum estimation.

Multiple comparisons in study IV. As 164 separate comparisons were made between the exposure and effect variables it could be argued that the results of study IV in this thesis could be explained by chance associations alone, an effect of "multiple comparisons". No adjustments of the level of significance were made, as confidence intervals were calculated and as such methods have been criticised [178]. However, the criteria for "pronounced association" have a similar conservative effect as e.g adjustment of the significance level. The main arguments against chance as an explanation for the results are that they are biologically plausible, had a consistent pattern and were tested against a priori hypotheses [178]. The included "check" medical examination items, which were supposedly less likely to be associated with the exposure variables, showed no such "chance" associations.

Cause-effect relations. It is not possible to draw definite conclusions from this thesis about possible cause-effect relations between individual characteristics, injuries, diseases, and exposure factors at work and AER signs of nerve compression in the brachial plexus. The number of incident cases was too low for any detailed analysis. A case-control study would be more efficient. Neither is it possible to draw any definite conclusions about true brachial plexus entrapment as no objectification of such processes was carried out.

No definite cause-effect relations can be inferred about psychosocial conditions at work and MSD, partly due to the cross-sectional design of study IV in this thesis and partly due to the absence of objectification of the psychosocial conditions. The findings in the study need verification in order to make interpretation of the results more definite.

6. Conclusions and summarising statements of this thesis

- The following rough estimations were made about neurological AER signs among male industrial and office workers in this study: cumulative incidence approximately 2/100 person-years; mean duration approximately 12-18 years; recovery rate approximately 8-9/100 case-years.
- Factors related to working conditions, constitution, disease, and neck trauma were associated with neurological AER signs.
- Neurological AER signs predicted future neck and upper-extremity symptoms and signs of nerve compression.
- Prevention, evaluation and management of neck- and upper-extremity nerve compression disorders, focal or multiple, should address all potential foci of traumatisation, including the brachial plexus. The AER test is a supplementary tool in such work, both in epidemiology and in occupational health settings.
- The results in this thesis support the “double or multiple crush” theory of nerve compression injury.

- The self-administered examination method used in this thesis was not valid and therefore not suitable to *replace* a traditional medical examination for identifying subjects with positive signs of disorders in the musculoskeletal system of the neck and upper extremities in epidemiological studies.
- Self-administered examination of *tenderness* can be used as a *screening method in analytical studies* of relations between exposure and signs of musculoskeletal disorders.

- Perceived high psychological demands, high job strain or low social support were statistically associated with both symptoms and signs from the musculoskeletal system.
- Such associations were most pronounced with symptoms and signs from central body regions, i.e. neck and low back, compared to more peripheral regions such as arms or legs.
- The associations were more pronounced with signs of muscular (soft tissue) tenderness compared to signs of affections of nerves, joints, tendons or muscular insertions.
- Studies of associations between psychosocial work conditions and musculoskeletal disorders should separate effect measures of different signs and different body regions in order to avoid attenuation of the risk estimates.

- Pain drawings of neck, shoulder and upper-back symptoms among middle-aged general working population were most usually located to the neck-shoulder angle with a symmetrical left-right distribution.
- Women reported larger, more central, bilateral and symmetrical symptom areas than men.
- The number of separate symptom loci, their total area, left-right distribution and symmetry were characteristics associated with symptom chronicity and severity or signs of tenderness in the neck-trapezius region.

- There was no support for the existence of a range of high and low rating behaviour among middle-aged subjects who rate neutral and non-affective stimuli, such as time, weight, number and physical exposure, but also pain and other symptoms.
- There is therefore no support for the idea of a bias to relative risk estimates from such rating behaviour in studies where subjects rate both exposure and outcome variables of this kind.

7. New aspects in this thesis

As far as could be found in the published literature, mainly the following research issues, methods used and results have not been reported earlier.

- Estimation of cumulative incidence and prognostic factors of neurological signs of brachial plexus compression during the AER test (Study II).

- The finding of asthma as a possible risk factor for brachial plexus compression (Study II).

- Highlighting the implications of the “double and multiple crush” theory of nerve compression for prevention, evaluation and rehabilitation of neck and upper extremity disorders (Study II).

- The development and evaluation of a protocol of self-administered examination of signs in the neck and upper extremities (Study III).

- The study of the relation of self-reported psychosocial working conditions to specific locations and characteristics of musculoskeletal disorders (Study IV).

- The registration of a wide range of specific signs of MSD in studying psychosocial work conditions (Study IV).

- The use of high resolution pain drawings in the neck and shoulder regions among the working population with further attempts to quantify its characteristics (Study V).

- The topographical presentation of aggregated pain drawing results (Study V).

- The postulation and evaluation of high and low rating behaviour and its possible biasing effect to risk estimates (Study VI).

8. Summary

Toomingas A. Methods for evaluating work-related musculoskeletal neck and upper-extremity disorders in epidemiological studies. Thesis at Karolinska Institute, Stockholm. National Institute for Working Life, Arbete och Hälsa 1998:6.

The aim of this thesis was to develop, evaluate and characterise assessment methods used within epidemiological studies of work-related musculoskeletal disorders in the neck and upper extremities. Special attention was paid to self-administered methods, relations to psychosocial risk factors and signs of nerve compression.

Work-related musculoskeletal disorders in the neck and upper extremities are common and costly in many respects. Knowledge about the progression of these disorders and their causality, especially in relation to psychosocial conditions, is insufficient. Methods, mainly self-administered, for their assessment in epidemiological studies are limited.

Main affected structures, common disorders and their symptoms and signs, different assessment methods and their qualifications were discussed in this thesis. The existence of a high and low rating behaviour was proposed. If both exposure and outcome are rated by the subjects in an epidemiological study, such a rating behaviour could introduce uncontrollable bias to the risk-estimates, most commonly an over-estimation. No such rating behaviour was found, however, and no effects on risk estimates could be demonstrated.

A self-administered physical examination protocol was developed and evaluated against traditional medical examination. The validity was poor, however. A self-administered pain drawing method was developed and studied among working population with symptoms in the neck and shoulder regions. The average outline showed two palm-sized areas in the neck-shoulder angles, with a symmetrical distribution between the right and left sides. Long-lasting or severe disorders and signs of tenderness were associated with large areas and multiple loci. Gender differences were noted.

The brachial plexus can be compressed in several locations in the neck and shoulder region. The diagnosis of this compression is mainly based on symptoms and medical examination, where the Abduction External Rotation test has been used. Prospective aspects and the outcome of the test were studied among male industrial and office workers. The results gave support to multi-causality and to the “double or multiple crush” theory of nerve compression. Evaluation of neck and upper extremity nerve compression diseases should therefore attend to all probable locations of such compression, even when a specific location is in focus.

Psychosocial working conditions have been recognised as important risk factors for musculoskeletal disorders. This thesis gave support to the hypothesis that high psychosocial load has specific associations with symptoms and signs of muscular (soft tissue) tenderness from central body regions - the neck and back. Studies of these relations should therefore distinguish between different clinical signs and different body regions in order to avoid attenuation of risk estimates.

Suggestions were discussed for further development of reliable and valid methods for assessment of these disorders feasible for epidemiological studies and in health surveillance.

9. Sammanfattning (summary in Swedish)

Toomingas A. Methods for evaluating work-related musculoskeletal neck and upper-extremity disorders in epidemiological studies. Doktorsavhandling vid Karolinska institutet, Stockholm. Arbetslivsinstitutet, Arbete och Hälsa 1998:6.

Syftet med denna avhandling var att utveckla, utvärdera samt karakterisera epidemiologiska metoder att mäta arbetsrelaterad sjuklighet i nacke och övre extremiteter. Speciell uppmärksamhet ägnades åt självadministrerade metoder, relationen till psykosociala riskfaktorer samt tecken på nervkompression.

Arbetsrelaterade åkommor i nacke och övre extremiteter är vanliga och kostsamma ur många aspekter. Kunskaperna om sjukdomsutveckling och bakomliggande orsakssammanhang, speciellt i relation till psykosocial belastning, är otillräckliga. Metoder, speciellt självadministrerade, för att registrera dessa åkommor i epidemiologiska studier är begränsade.

Vanligen drabbade strukturer och åkommor, deras symptom och undersökningsfynd, olika registreringsmetoder och deras kvaliteter redovisades i avhandlingen. Förekomst av hög- resp. lågskattarbeteende föreslogs. Om både exponering och sjuklighet skattas av studiepersonerna i en epidemiologisk studie, kan ett sådant skattningsbeteende införa en okontrollerbar förvrängning av riskestimat, vanligtvis en överskattning. Något sådant skattningsbeteende kunde emellertid ej påvisas hos studiepersoner i denna avhandling, och ingen effekt på riskestimat kunde demonstreras.

Ett självadministrerat kroppsundersöknings protokoll utvecklades och utvärderades gentemot traditionell läkarundersökning. Överensstämmelsen var emellertid dålig. En självadministrerad smärtritningsmetod utvecklades och utprovades bland yrkesarbetare med besvär i nacke eller skuldror. Den genomsnittliga bilden visade två handflatestora områden i nack-skuldervinklarna med en symmetrisk vänster- och högersidig utbredning. Långvariga eller grava besvär samt tecken på ömhet var kopplade till stor markerad yta med flera focus. Köns-skillnader noterades.

Plexus brachialis kan bli utsatt för kompression på flera ställen i nacke och skulder regionen. Diagnostik av sådan kompression bygger främst på symptom och fynd vid kroppsundersökning där “Abduction External Rotation” testet har använts. Utfall och testets prognostiska faktorer samt värde studerades bland manliga industri- och kontorsarbetare. Resultaten pekade på en multifaktoriell bakgrund och gav stöd åt “double and multiple crush” teorin om nervkompression. Vid bedömning av nervkompression i nacke och övre extremiteter bör man därför beakta samtliga möjliga lägen för inklämning, även om bara ett visst är i fokus.

Psykosociala arbetsförhållanden har uppmärksammats som viktiga riskfaktorer för sjuklighet i rörelseorganen. Denna avhandlings resultat gav stöd åt hypotesen att hög psykosocial belastning har koppling till symptom och till ömhet i muskler (mjukdelar) specifikt i kroppens centrala delar – nacken och ryggen. Studier av sådana samband bör därför särkilja mellan kroppsregioner och olika typer av fynd vid kroppsundersökning för att undvika utspädningseffekter av riskestimat.

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