Advanced Knowledge Work and Stress-related Symptoms

Epidemiology and Clinical Intervention Studies

CLAIRY WIHOLM
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Abstract


Well educated knowledge workers are a growing group of the work force. Little research has been conducted on this group regarding possible work-related health symptoms, as well as interventions in order to reduce work-related stress. This thesis describes the current work-related symptoms and potential risk and salutogenic, i.e. protective factors, associated with these symptoms among software and system designers in a high tech company in Sweden. A stress management intervention program was launched in order to evaluate whether work-related stress might be a risk factors for these symptoms. It was also of interest to study the potential impact of stress management interventions on psychosocial work organizational factors.

The thesis is based on cross sectional and longitudinal data. Paper I is focusing on risk factors for musculoskeletal symptoms and headaches, and their possible association with biological markers and self-reported physical and psychosocial work environmental factors. Paper II assessed the association between occupational psychosocial factors and psychosomatic symptoms i.e. mental fatigue, headache, restlessness, irritation, moodiness and difficulty concentrating. Paper III and IV evaluated the effects of a stress management program including three different stress reducing strategies, on musculoskeletal and skin symptoms as well as headaches, and on the perceived psychosocial work environment.

The overall results indicate that psychosocial factors via stress sensitive hormones have an impact on employee health in a high technological work environment. Furthermore, stress management interventions, conducted as relaxation and mental training, had short-term favorable effects on some musculoskeletal and skin symptoms. It seems that competence and competence utilization among advanced knowledge workers are psychosocial work environmental factors that need to be take into consideration in future health preventive ventures.

Keywords: musculoskeletal, hedache, skinsymptoms, physiology, psychosocial, stress management, intervention

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List of papers

This thesis is based on the following papers. In the manuscript they will be referred to as:

Paper I

Paper II

Paper III

Paper IV
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### Abbreviations

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<tr>
<td>A</td>
<td>Epinephrine</td>
</tr>
<tr>
<td>ACTH</td>
<td>Adrenocorticotropic</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Statistical method. Analysis of variance</td>
</tr>
<tr>
<td>AVP</td>
<td>Arginin vasopressin</td>
</tr>
<tr>
<td>AXE</td>
<td>Ericsson Telecommunication system</td>
</tr>
<tr>
<td>CNS</td>
<td>Central nervous system</td>
</tr>
<tr>
<td>CRH</td>
<td>Corticotropin releasing hormone</td>
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<tr>
<td>HPA</td>
<td>Hypothalamic-pituitary-adrenal</td>
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<tr>
<td>HPG</td>
<td>Hypothalamic-pituitary-gonadal</td>
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<tr>
<td>IG</td>
<td>Intervention group</td>
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<tr>
<td>IP</td>
<td>Intervention program</td>
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<tr>
<td>IS/IT</td>
<td>Information System / Information Technology</td>
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<td>MSS</td>
<td>Musculoskeletal symptoms</td>
</tr>
<tr>
<td>NA</td>
<td>Nor epinephrine</td>
</tr>
<tr>
<td>NO</td>
<td>Nitric oxide</td>
</tr>
<tr>
<td>O2</td>
<td>Oxygen</td>
</tr>
<tr>
<td>PCO2</td>
<td>Peak concentration of carbon dioxide in a single breath of exhaled air</td>
</tr>
<tr>
<td>PPB</td>
<td>Physical-Psycho-Biological</td>
</tr>
<tr>
<td>RG</td>
<td>Reference group</td>
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<tr>
<td>RTM</td>
<td>Regression towards the mean</td>
</tr>
<tr>
<td>SAM</td>
<td>Sympathetic adrenomedullary</td>
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<tr>
<td>VDU</td>
<td>Visual Display Unit</td>
</tr>
<tr>
<td>UNIX</td>
<td>Computer operating system</td>
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<tr>
<td>USD</td>
<td>American dollar</td>
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Introduction

Background
Nearly three decades ago substantial structural changes in working life started to occur, due to the introduction of IS/IT (Information System/Information Technologies). Most areas of working life were affected in terms of cutbacks, reorganizations, outsourcing, new skills requirements, and aggressive competition in many branches, leading to either company success or failure. At the same time the work-related disease panorama seems to have changed from low back disorders in physically heavy work situations to more unspecified musculoskeletal disorders in jobs characterized by static load, monotonous movements, and repetitive tasks (Borg, Kristensen et al. 2000). In Sweden between 1989 and 2001 the prevalence of symptoms and pain in the neck-shoulder region, at least once a week, increased by 30% for males from 18.9 to 24.5 per cent, and 27% for women from 31.8 to 40.4 per cent (Melin and Wigaeus 2005). When the computer became a more common working tool, new work-related ill-health symptoms were reported, i.e. skin disorders (Nilsen 1982; Bergqvist and Wahlberg 1994), non-migraine headache and eyestrain (Gunnarsson and Soderberg 1983; Vincent, Spierings et al. 1989; Aronsson and Stromberg 1993).

The main focus regarding work-related risk factors for musculoskeletal disorders has been on work posture and workplace ergonomics. During the 90s psychosocial and organizational issues were added to the potential risk factors for these symptoms (Fahrbach and Chapman 1990; Leivoska and Keinanen-Kiukaanniemi 1994; Lundberg, Kadefors et al. 1994; Faucett and Rempel 1996; Arnetz, Berg et al. 1997; Melin and Lundberg 1997; Conway 1999; Eriksen, Natvig et al. 1999; Fredriksson, Alfredsson et al. 2000; Mocci, Serra et al. 2001; Lundberg and Melin 2002; Cho, Hwang et al. 2003).

Stress at work has been reported as a risk factor for work-related musculoskeletal disorders by many authors. Recent studies suggest that work with visual display units (VDU) might result in psychophysiological stress with measurable changes in stress-sensitive hormones (Lundberg, Kadefors et al. 1994; Arnetz 1996; Haufler, Feuerstein et al. 2000; Hanse 2002; Lundberg 2003). Such neurobiological change is suggested to affect the musculoskeletal system, contributing to pain and disorders (Henry 1992; Arnetz 1996; Korunka, Huemer et al. 1996; Melin and Lundberg 1997; Holte and West-
gaard 2002; Knardahl 2002; Lundberg and Melin 2002). Most authors today suggest that the causation of these symptoms is multifactorial and due to both physical as well as the psychosocial (work) environment combined with individual characteristics (Miranda, Viikari-Juntura et al. 2005). This broader description is supported by WHO in their statement that musculoskeletal conditions have multifactorial causes with risks related to the work environment as well as to individual, lifestyle, and socio-cultural factors.

With the introduction of VDU at the workplace, reports of dermatological symptoms from working withVDUs increased, suggesting an association between VDU exposure and skin symptoms (Nilsen 1982; 1988; Berg, Arnetz et al. 1992; Eriksson, Hoog et al. 1997). One epidemiological study theorized that even if self-reported skin symptoms were more common among VDU users there were no significant differences between VDU-exposed and non-exposed groups in objective signs of skin disease (Berg, Liden et al. 1990). However, Berg (1989) reported in his doctoral thesis that most patients that had a dermatological examination because they were suspected of having skin disorders related to VDU work showed ordinary facial skin disorders, and half of them had rosacea. Two thirds of the subjects recovered without treatment in spite of continuing work with VDUs. The author suggested these unspecific skin symptoms could be explained by the mass media campaign claiming that VDU work caused skin disease.

There are innumerable interventions that aim at improving the work environment in order to reduce musculoskeletal symptoms, headache, and skin symptoms as well as eyestrain. Most common through the years are ergonomic interventions aiming at improving the physical work environment, e.g. keyboard placement, desk and chair adjustments. Physical exercise interventions during working time have been reported as beneficial (Sjogren, Nissinen et al. 2005). Furthermore visual and lighting interventions have been conducted in order to reduce eyestrain and headache.

To reduce skin symptoms in the VDU work environment, different interventions aimed at reducing electric and magnetic fields have been conducted on individual as well as organizational levels, e.g. (Arnetz, Axling et al. 1992). The results of these studies are positive in the sense of showing an improved objective and self-assessed work environment and a decrease in the self-reported symptoms (Saito, Miyao et al. 1997; Faucett, Garry et al. 2002; Arnetz, Sjogren et al. 2003; Robertson and O'Neill 2003; Melhorn and Gardner 2004; Dainoff, Cohen et al. 2005). Despite increasing knowledge regarding risk factors and successful interventions the reported ill-health symptoms (i.e. musculoskeletal as well as eyestrain) have not decreased in general.

Changes in work conditions and demands have probably impacted on employee health as well. The performance capacities of employees as well as the demands in general have increased substantially, whereas the ways in which humans react to strain and demands have remained unchanged. Both
psychological and physiological reactions to stress in the work environment
are governed by archetypes of stress reactions which persisted for centuries.
These work-related ill-health symptoms do not only cause suffering for the
individual; they also impact costs, i.e. in decreased efficiency during work
and in lost productivity (Hagberg, Tornqvist et al. 2002; Boles, Pelletier et
al. 2004; Pelletier, Boles et al. 2004).

Aim of this thesis
The aim of this thesis was to contribute to further knowledge concerning
work-related symptoms among well-educated employees working in a high
tech work environment, and also to discuss possible effects of stress man-
agement intervention. More specifically, to

- Identify psychosocial as well as physiological risk factors
  associated with increased musculoskeletal symptoms, skin
  symptoms, and headache. (Paper I)
- Investigate psychosocial work environmental factors and
  their possible associations with psychosomatic symptoms
  such as mental fatigue, headache, restlessness, irritation,
  moodiness, and difficulty concentrating. (Paper II)
- Assess the direct and long-term effects of a stress manage-
  ment intervention program on biological stressmarkers. (Pa-
  per III).
- Assess the direct and long-term effects of a stress
  management intervention program on musculoskeletal
  symptoms in the neck/back, shoulder and the lower arm as
  well as on skin symptoms and headache. (Papers III, IV)
- Study the impact of stress management intervention
  programs on the perceived psychosocial work environment.
  (Paper III, IV).

Overall hypotheses
It was hypothesized that

- Psychosocial work environmental factors are associated with
  neck/back, shoulder, arm, and skin symptoms as well as
  with headache.
- Lower levels of circulating testosterone and higher levels of
  serum prolactin and cortisol are associated with increased
  neck/back, shoulder and arm symptoms and with skin symp-
  toms as well as with headache.
Psychosomatic symptoms such as mental fatigue, headache, restlessness, irritation, moodiness and difficulty concentrating are associated with the perceived psychosocial work environment.

A stress management intervention program has a positive impact on biological stress markers.

Good stress management ability is inversely associated with musculoskeletal and skin symptoms.

Stress management intervention programs have a favorable impact on the perception of psychosocial work environment.

A brief introduction to common work-related symptoms

Musculoskeletal symptoms

Musculoskeletal symptoms without clinical findings are rather common in the general population. A Finnish survey (Miranda, Viikari-Juntura et al. 2005) reported that 12% of a study group of 8028 persons reported non-specific shoulder pain, while 2% reported specific musculoskeletal symptoms, e.g. rotator cuff tendonitis. Nonspecific pain was related to psychosocial factors.

Ariens et al. (2000) presented a systematic review of the literature on physical work environmental factors and neck pain, a total of 25 studies. The results revealed some evidence for a significant association between the duration of sitting and twisting or bending of the trunk and ratings of neck pain. During the last two decades the focus on exposures for work-related musculoskeletal symptoms has broadened to include psychosocial and organizational factors. In 2002, Bongers et al. (2002) published an extensive review of the literature on the role of psychosocial factors in the development of musculoskeletal problems. The conclusion was that high job stress, perceived high job demands, and non-work-related stress reactions are consistently associated with upper extremity symptoms. Psychosocial factors, i.e. mental workload, monotonous work, poor autonomy regarding one’s job, and poor social support seem to be common risk factors for musculoskeletal neck and shoulder symptoms at work (Toomingas, Theorell et al. 1997; Elander, Takala et al. 1998; Eriksen, Natvig et al. 1999; Hanse 2002; Halford and Cohen 2003; Wahlstrom, Lindegard et al. 2003; Bystrom, Hanse et al. 2004; Cail and Aptel 2005).

Employees reporting musculoskeletal symptoms are advised to cope with their symptoms by changing work posture and working techniques. This change might be difficult due to negative social and organizational factors. It seems that decision authority and social and managerial support are important contributors to the coping process of musculoskeletal symptoms (Torp,
Empirical research has shown that both physical and mental load increased the trapezius muscle activity (Lundberg, Forsman et al. 2002; Holte, Vasseljen et al. 2003; Krantz, Forsman et al. 2004). It seems that low threshold motor units in the trapezius muscle have different exhibit patterns in slow and fast muscle contractions (Westgaard and De Luca 2001). Furthermore, trapezius activity patterns in response to stress have similar patterns to those that would be expected from a muscle which induces pain symptoms. The combination of physical and mental strain increased the muscle activity in the trapezius muscle more than only physical or mental load did, suggesting a synergetic effect (Lundberg, Mardberg et al. 1994). Though musculoskeletal symptoms in the neck, shoulder, and arm are common ill-health problems in the industrialized world, the etiology for these symptoms is not fully understood (Knardahl 2005).

There are different theories explaining possible causes for the origin of these symptoms.

Theories linking stress with musculoskeletal symptoms within a frame of the allostatic load model

**The allostatic system**

The concept of internal environment was developed by Cannon (1939) in the first part of the 20th century. He introduced the term *homeostasis*, i.e. a coordination of physical processes with the goal of obtaining steady states in the organism during emergencies by activation of the sympathico-adrenal system. The physiological activations that are needed in order to maintain or reestablish homeostasis differ, depending on the actual situation of the organism. The level of required activation in order to obtain a steady state during change is called *allostasis*, while *allostatic load* refers to the effects of the long-lasting activations of the different effectors involved in the allostasis (Goldstein and McEwen 2002). In a long-term stressful situation one or more of the involved effectors might be activated constantly. This theory, also described as the wear and tear cost of adaptation, has been suggested as constituting a basis for different ill-health symptoms (McEwen 1998). It could be theorized that an over- or under-activation of the allostatic system might contribute to musculoskeletal symptoms and skin symptoms. The model is further discussed under the stress introduction on page 20.

**The hyperventilation theory**

Schleifer (Schleifer and Ley 1994; Schleifer, Ley et al. 2002) suggested that stressful events increase hyperventilation, resulting in decreased PCO₂ (pulmonary) levels in the arterial blood system. This dysfunction in the acid-base equilibrium activates systemic physiological reactions resulting in an increased muscle tension and muscle ischemia and hypoxia. The change also
affects the potassium ions in the blood and might result in a disturbed muscle function. Furthermore a shift from a diaphragmatic breathing pattern to a more thoracic breathing pattern will increase the biomechanical response load on the neck and shoulder muscles, i.e. the trapezius, sternocleidomastoid, and the scalene muscles.

The migraine theory
Another theory regarding long-lasting static load and the arousal of musculoskeletal pain disorders has been suggested by Knardahl (2002). According to this theory, the interaction between sensory nerves and blood vessels dilate the blood vessels affecting the muscles, causing pain similar to attacks of migraine. This hypothesis suggests a reciprocal action between sensory nerves and blood vessels, without any direct involvement of the muscle fibers. The author discusses three possible mechanisms for this mutual activity, including 1) arterial vasodilatation resulting in an extension of the blood vessels, stretching the actual tissues including nerve endings, 2) an increase of pain-inducing substances resulting in pain and irritability, and 3) these contributing to an inflammatory process with an increased permeability of the vessels.

The muscle spindle theory
Johansson and Sojka (Johansson and Sojka 1991) have proposed a theory, based on the assumption that the body defense system against monotonous movements is linked to the stress management system. The long-term static load causes dysfunctions in the muscle spindle system, due to acid substances as metabolites in the blood, causing an increased activity in the nerve cells which affect the muscle spindle system. The blood flow in the muscles impairs and “vicious circles” arise, exciting the nerve cells even more, followed by an increased muscle spindle activity.

The Cinderella theory
The Cinderella theory proposed by Hägg (1991) is based on laboratory research describing a stereotypical recruitment pattern of motor units during a muscle contraction, i.e. that the small and sensitive motor units that are first activated in a muscle contraction are also the ones that are shut down last when the static load is stopped. This might result in over-activation and exhaustion with intramuscular metabolic effects on these motor units. The pain and the inflammatory reactions in the muscle are, according to this theory, due to insufficient recovery.

The nitric oxide/oxygen ratio hypothesis
It is also suggested that both psychological stress and prolonged head-down neck flexion may increase sympathetic nerve activity resulting in a vasoconstriction with reduced capillary blood flow and intracellular oxygen in the
muscles as well as a reduced nitric oxide removal (Shortt and Ray 1997). An imbalance in the O$_2$/NO system might affect the mitochondrial function (Moncada and Erusalimsky 2002). According to the theory this phenomenon only occurs during long-lasting low-intensity muscle contraction.

Common to all these theories is that mental stress has an important impact on each of the described theories.

VDU-related skin symptoms

Unspecified skin problems, also called *hypersensitivity to electricity* during VDU work, were reported as early as the beginning of the 1980s (Linden and Rolfsen 1981; Knave, Wibom et al. 1985). The symptoms were a burning feeling in the skin, sometimes oversensitivity to daylight, and symptoms including dizziness, headache, nausea, and musculoskeletal pains (Hillert 2001). Other authors have reported similar findings (Berg, Liden et al. 1990; Eriksson, Hoog et al. 1997; Bergdahl, Stenberg et al. 2004). However, no specific skin disease or histological changes could be identified among subjects with VDU-related skin symptoms (Berg, Lonne-Rahm et al. 1998). A number of provocation studies in laboratory environment have been executed in order to find evidence-based facts that electromagnetic fields cause the reported skin problems (Lonne-Rahm, Andersson et al. 2000). In 2004, a literature review based on 31 provocation studies was published (Rubin, Das Munshi et al. 2005). The conclusion was that there “is no question that the symptoms reported by electromagnetic hypersensitivity sufferers are real. However it has been difficult to show under blind conditions that exposure to electrical and magnetic fields can trigger these symptoms”. It is well documented that skin disorders cause stress, but there are few reports about stress causing skin symptoms. However, one theory presented by (Altemus, Rao et al. 2001) suggests that stress and sleep deprivation decrease the water content in the stratum corneum, effecting the barrier function and resulting in possible skin symptoms. Furthermore, Dhabhar and McEwens (1999) have reported evidence showing that acute stress via adrenocortical stress hormones in rats increased the skin immune function, while long-term stress had an opposite effect. However, to date there is no conclusive evidence that VDU tasks per se would result in an increased risk of skin disorders.

Headache

In 2004 the International Classification of Headache Disorders (1988) released a second edition regarding diagnostic criteria for headache. The diagnostic criteria for tension-type headache include 1) the headache should not be aggravated by routine physical activity and 2) the headache must not be caused by another disease. The exact mechanisms for tension-type headache are not fully understood. Most likely, peripheral pain mechanisms are in-
volved in episodic headache, while central pain mechanisms probably are involved in chronic tension-type headache (Fumal and Schoenen 2005).

Tension-type headache seems to be a common problem for a wide range of people in our society. A Belgian study reported that about 80% of the general population suffer from episodic tension-type headache, while 3% have chronic symptoms (Fumal and Schoenen 2005). A Danish population-based study reported that 59% reported symptoms i.e. headache during one day a month or less and 37% had symptoms several times a month. Tension-type headache is more common among females and there seems to be a prevalence peak between ages 30-39. Besides gender and age, social group was also a significant factor i.e. those in lower income groups and with less education seemed to report more tension headaches (Lyngberg, Rasmussen et al. 2005). It is also recognized that headache is the largest contributor to productivity loss time among the US work force (Stewart, Ricci et al. 2003). A Swedish survey (Raak and Raak 2003) reported that 39% of the private employee population and 57% of the public employees reported headache due to stress. Based on the results of this study the authors calculated the cost of lost effectiveness due to headache among employees in Sweden to be approximately 1.4 billion Euros per year. It also seems that tension-type headache patients are more disposed to developing shoulder and neck pain when they are exposed to static loads (Christensen, Bendtsen et al. 2005). However, Mongini et al. (2005) reported that there were no significant differences in muscle tenderness between chronic tension-type headache patients and chronic migraine patients. Relaxation training, muscular biofeedback and cognitive techniques are treatments that have shown a positive effect on tension-type headache.

Psychosocial work environment

The interactions between social work environmental factors as well as organizational factors and individuals at the workplace are defined as the psychosocial work environment. This means that the social climate, organizational issues, responsibility, and demands as well as decision latitude regarding one’s job have an impact on the individual’s health and well-being at work.

Over the years, there have been numerous models presented to explain the interrelationships between psychosocial factors, personal resources (such as cognitive resources, coping style, social support, genetic characteristics, prior experience, and psycho-physiological responses) and, ultimately, health and well-being. Among these models, Kagan and Levi (1974) presented a general theoretical model that outlined the association between internal as well as external environmental factors and ill health (see Figure 1).
The Kagan and Levi model is a theoretical systems model. In order to apply this approach to a workplace, the Model of Work system by Carayon-Sainfort (1999) has been used as a platform. This model links the interactions between technology, organization, task, and environment to human functions and work-related musculoskeletal symptoms. It is described as a framework for examining job stress, comprising five elements. These include task, environment, organization, technology, and individual characteristics. In the task element, the authors have included workload factors such as quantitative and qualitative under-load and overload. The organizational element is the context in which the work is done, i.e. career consideration, over- or under-promotion, lack of job security, work schedule, overtime, etc. The technological aspect of work comprises physical and mental requirements, software usability, and system support. The environmental element comprises both physical as well as psychosocial factors, such as social support and skills utilization. Both models demonstrate the complexity of the interaction between environmental factors, individual characteristics, work environmental factors, and possible ill-health outcomes.

Stress

Hans Selye was the originator of the biological stress definition. He called this phenomenon *Stress* and the word stress has ever since then been used both for the stimuli and for the reactions to the stimuli.
A stressor (stimulus) can be described as an internal or external physical or mental load which constitutes a potential threat to an individual’s homeostasis. According to Goldstein and McEwen (2002) stress could be defined as “a condition where expectations, whether genetically programmed, established by prior learning or deduced by circumstances, do not match the current or anticipated perceptions of the internal or external environment, and the discrepancy between what is observed or sensed and what is expected or programmed elicits patterned compensatory responses”. The reaction to a stressor can be cognitive, affecting the intellectual capacity e.g. memory or concentration ability. Emotionally it can cause anxiety, moodiness, and depression. The stress reaction can be behavioral or physiological and therefore the behavioral reactions might result in destructive life patterns contributing to the metabolic syndrome (Bjorntorp 2001), a growing health hazard in the Western world. The physiological reaction results in increased blood pressure and heart rate, as well as an increased muscle tension. All of these are common ill-health symptoms associated with stress.

Psychophysiological stress

All stressors, whether internal or external, activate the biological stress response via the central nerve system (CNS), the endocrine and immune systems, or via the sympathetic nervous systems (SAM). The hypothalamus-pituitary-adrenal axes (HPA) and the autonomic nervous system (ANS) are responsible for mediating information regarding stressful situations to different organs. The information passes via nerve impulses or blood circulation, changing the metabolism in the organs in order to help the individual to handle the aroused situation. Fig. 2 depicts a schematic view of the stress response and feedback system on a molecular level.

During stress the internal secretion of corticotrophin releasing hormone (CRH) increases, further stimulating the pituitary gland to increase the internal secretion of adrenocorticotropic hormone (ACTH). ACTH is transported to the adrenal cortex, which in turn releases cortisol. The CRH also affects the sympathetic nerve system activity, resulting in an increase in catecholamines. Stress also has an impact on the hypothalamus-pituitary-gonadal axis (HPG) with a reduced internal secretion of gonadotropin affecting both female and male sexual functions (Ekman, Arnetz et al. 2002).
Psychosocial stressors – different models

A psychosocial stressor can be social, economical, or caused by organizational circumstances (Melin, Lundberg et al. 1999) at work. There are in general two leading theoretical models of psychosocial factors and stress, the Demand/Control model (Karasek and Theorell 1990) and the Effort-Reward model (Siegrist 1996).

Reasonable work demands, use of skills and enough control (autonomy) in decisions that concern one’s work have been described and reported by authors including Karasek and Theorell (1990) to be important parameters for employee health and well-being. The Demand/Control model describes the association between demands of work, skills use, and task control in one’s work. The outcome measure, decision latitude in relation to psychological demands, has been reported to correlate with strain symptoms and depression (Karasek and Theorell 1990). The Effort-Reward model reported by Siegrist (1996), depicts the association between perceived effort put into one’s job and the reward in terms of appreciation, salary and career opportunities. If the effort is bigger than the perceived reward this might lead to stress.

Furthermore coping ability and social support are important factors to take into consideration when analyzing the effects of stress (Lazarus 2000). Lack of social support has been reported to be a risk factor for heart diseases.
(Orth-Gomér, Horsten et al. 1998; Wang, Mittleman et al. 2005). Orth-Gomér (2001) reported in her study that the stress-induced risk of recurrent cardiac events in women was non-significant when the individual coping capacity to stress was high. However, women with low coping capacities had the highest risk of recurrences. Other work-related stressors reported are introduction of new technologies (Korunka, Huemer et al. 1996) and skills utilization (Mocci, Serra et al. 2001).

**Competence and skills utilization**

Competence and skills development are stated in many modern companies today to be an individual responsibility, ensuring future employability. Demanding job tasks with a high degree of control might actually facilitate skills development. Based on the demand/control model, Paulsson et al. (2005) have reported that increased workers’ control of the learning process makes competence development more stimulating and reduces competence stress. If competence development is seen as an individual responsibility, employee skills utilization might be seen as a managerial responsibility and thereby a psychosocial work environmental factor. There are few studies conducted on the association between skills utilization and employee health. However, Mocci (2001) reported that under-utilization of skills significantly correlated with asthenopia (eyestrain), a rather common complaint in VDU operators.

**Physical environment**

Physical work environmental factors and their impact on employee health were studied and reported even in ancient Greece. It would be too ambitious to even try to cover the huge amount of research in the literature. However, physical work environmental factors of importance in modern offices reported to correlate with employee health are: work posture and work movements, indoor climate, electrical environment, visual ergonomic environment, and man/machine computer interface (Sauter, Schleifer et al. 1991; Karlqvist, Hagberg et al. 1994; Saito, Miyao et al. 1997; Ariens, van Mechelen et al. 2000; Fallentin, Viikari-Juntura et al. 2001; Hansson and Westerholm 2001; Janosik and Grzesik 2003; GC 2005).

**Stress management; muscular relaxation training**

Stress has been discussed as a risk factor for musculoskeletal and skin disorders as well as for headache. The concept of stress management comprises a large range of different interventions, i.e. coping strategies, education, practical workplace training, and different behavioral techniques (Ong, Linden et al. 2004). In this thesis, stress management is used as a synonym for three
kinds of muscular and mental relaxation training. It is of interest to review briefly the current literature concerning the relationship between, on one hand, stress management and musculoskeletal symptoms, skin symptoms and headache, and on the other hand, the applications of different stress management techniques. Studies of stress management training have been carried out on rheumatoid arthritis patients in order to study the effect on pain and potential pain reduction (Stenström 1999; Multon, Parker et al. 2001). Other studies have been conducted to investigate the effect of stress management on cardiovascular reactions (Peters, Benson et al. 1977; Yung, French et al. 2001).

Anxiety and depression are two large fields where different stress management interventions, including applied behavioral training as well as muscular relaxation training, have been frequently used (Öst 1987; Brady 1995; Schultz 2002). Muscular relaxation training as a non-invasive treatment for asthma (Ritz 2001) and tension-type headache has been reported (Nash 2003). Well-controlled studies conducted in order to evaluate the effects of stress management on musculoskeletal symptoms have been reported by authors including (Toivanen, Helin et al. 1993; Victor and Richeimer 2003; Viljanen, Malmivaara et al. 2003). Furthermore it seemed as if stress management per se had an impact on stress with decreased salivary cortisol levels, significantly lower levels of perceived stress, and an increased self-reported level of relaxation (Pawlow and Jones 2002). Stress management conducted as muscular relaxation training is a common mode of treatment of different kinds of pain symptoms. The relaxation techniques in the different studies varied; nevertheless, most studies reported a decrease in the measured symptoms directly after the termination of the intervention. Relaxation training in combination with physical therapy or behavioral therapy seemed in some of the reports to be more beneficial on the studied symptoms than relaxation training alone (Murphy 1996).

Why study employees in a high-tech work environment?

As a physical therapist in the occupational health department at the Ericsson Corporation, work-related musculoskeletal symptoms were common disorders on my daily agenda. The typical patients were females, working at assembly tasks or in the office with word processing and other computer work. In the end of the 1980s this “patient picture” changed. A new patient category appeared, young, well-educated men, working in a development company with cutting edge technology. They reported similar unspecified musculoskeletal symptoms from the neck and shoulder as had the former patient group. This new ill-health population stimulated questions about which work environmental factors might correlate with these symptoms in a development
company that was well-reputed for its high focus on work environmental factors. Are there possible new stressors in this work environment or are there different integrations between already reported psychosocial stressors? Furthermore, employees in a high-tech development company, i.e. software and hardware designers, were mostly men, both developing and using the new technology which will be the common technology in most workplaces within a foreseeable future. In order to promote the project as the only work form for technical development the company created a matrix organization made up of a strong project organization and a weaker line organization. It was common for the management to have two roles, one as line manager and one as project manager. These combined roles could be conflicting, causing uncertainty in the line and the projects. We believed that the results of our research might contribute more knowledge to the large, complex research field of VDU-related ill health in modern offices.

The studied company
The Ellemtel Telecommunication System Laboratories was a development company involved in advanced telecommunication system design. The company was owned jointly by the Swedish Telecom and Ericsson Corporation. From the end of 1980s to the middle of 1990s, the company expanded from 500 to 1700 employees. At the time of the studies, the company was facing major changes. The reason for this necessary change in the company was a new assignment, the future follow-up of the AXE telecommunication system, which had been developed earlier in the company. At the time of the new project, Ellemtel was a service and maintenance organization for AXE. New technical competence was required and the company was enlarged with highly skilled research and development employees. At the same time the computer system was changed from mainframe computer operation to personal computer operations, including powerful color UNIX workstations. The change to personal computer systems had an impact on the work environment. The work became more fixed when the employees did not need to leave the office and move to the computer rooms. Furthermore the text-based interface was changed to a graphic one and the mouse was introduced as a new input device. New expertise was also required in order to handle this new work tool, the personal computer. The main project was one of the largest industrial projects in Sweden at that time and the overall project goals were secret. The motto was, "The sky is the limit, money is not an issue". According to a work environmental survey conducted in the early 1990s, the employees perceived their work environment as having a high degree of autonomy, high demands, great opportunities for personal development, and as being exciting and challenging (report on file). Thus, with this background, the focus will be on the study design and the study population that was the basis of this thesis.
Material & methods

Study population

All four papers in this thesis are based on a major work environmental intervention carried out at the Ellemtel company between 1993 and 1995.

The study population in all four studies was comprised of a sample of telecommunication designers or other technicians working in two different departments in a high tech development company. The participants were mostly university-educated engineers engaged in advanced IT-based software and systems development.

Participants were 30-39 years old at the time of the study and 21% were women. (The percentage of women in the company as a whole was 20%). In their daily tasks the participants used powerful workstations approximately 50% of the workday, primarily designing software for new telecommunication systems. Both selected departments had become responsible for a global education program in addition to their ordinary work tasks and were expected to face a substantial increase in workload in the coming year.

To qualify for inclusion in the study an employee had to be:

- Permanently employed at the company.
- Assigned to one of the selected departments or on temporary assignment in one of the selected departments, with the assignment scheduled to last for at least another year.
- Working at the time of recruitment to the program. People on sick leave (approximately 2%) were not included in the study.

There were no statistically significant differences between the employees of the two selected departments in age, gender, job classification, educational background, or tenure at the company. Furthermore, no significant differences existed in gender, age, job classification, educational background and tenure between those who decided to participate at the two departments and a large sample of employees at the company who had responded to a previous occupational health survey at the workplace. Women in the study did not differ from men with regard to education or age but they had a shorter tenure within the company.
Methods

In order to test the hypothesis that psychosocial, self-reported physical work environmental factors as well as individual characteristic covary with work-related musculoskeletal symptoms, skin symptoms and headache, applicable cause and effect exploratory symptom models were reviewed. Besides the two models briefly presented in the introduction of this thesis, the Physical-Psycho-Biological (PPB) (Wiholm 2004) work model became the first operational platform for our work, linking the work environmental factors to psychophysiological parameters as well as to outcome variables, i.e. health symptoms.

![Physical-Psycho-Biological Work Model](image)

Figure 3. The physical-pseudo-biological work model. A revised model, accounting the possible interactions between biological markers, physical, and psychosocial environments and ill-health symptoms. (Wiholm 2004).

Our final work model, The Mission-Psychosocial-Work environment and Health model, further developed from the physical-psycho-biological model, is depicted in Figure 4. This model became the final platform for our work. The model suggests that the company mission has an impact on the psychosocial and physical environment. These current work environmental factors constitute the subjective and objective mental and physical workload. All individuals in the organization experience the current work environment in different ways. Depending on this perception and on different modifiers such as coping and social support, individual biological responses arise, resulting in various outcomes and sometimes in different ill-health symptoms.
Figure 4. *The Mission-Psychosocial-Work environment and Health model*, a theoretical model suggesting potential pathways from company mission to work-related ill-health outcomes.

**Paper design**

- Paper I is a cross-sectional study, N = 116 subjects.
- Paper II is a controlled longitudinal study, N = 135 subjects.
- Papers III and IV are longitudinal controlled intervention studies with an intervention and a reference group, N = 116 subjects.

**Assessments**

**Assessment tool**

All four papers are based on the same data collection set. A large 30-page questionnaire was used; it included questions about musculoskeletal symptoms, headache, skin symptoms, and psychosocial work environmental issues (Arnetz 1996; Arnetz 1999).

**Symptom indices**

Discrete Likert-type scales were used in the questionnaire. The ratings ranged from one to four, indicating from not at all to a high degree, or from disagree strongly to agree strongly. The scale score was achieved by adding individual item scores. The intensity of symptoms was scored as follows:
1 = no symptoms
2 = some symptoms
3 = considerable discomfort
4 = intense symptoms

Three different indices were constructed based on items in the survey questionnaire. Using exploratory factor analysis, two musculoskeletal (neck and back, lower arm) indices and one skin index were created. The internal consistency was confirmed using Cronbach’s alpha. Headache was assessed using a single factor, not an index.

Neck and back index
The neck and back index included symptoms from the neck (shoulder) and the upper and lower back (Cronbach’s alpha=0.86). The neck and back index ranged from a low of 3 points to a high of 12 points.

Lower arm index
The lower arm index consisted of symptoms from the elbow, lower arm, wrist, hand, and fingers (Cronbach’s alpha = 0.87). The range for the lower arm index was from a low of five to a high of 20 points.

Skin symptom index
The skin symptom index included the following symptoms: dry skin, itching skin, eczematous symptoms, skin rashes and pricklings (Cronbach’s alpha = 0.7). The range for the skin symptom index scale was from a low of five points to a high of 20 points.

The psychosocial work environmental assessment
The psychosocial components in the questionnaire covered socioeconomics and social lifestyle factors, the perceived physical and psychosocial work environments, years of computer work, percentage of workday spent in computer work, and hours at home with computer use. Other areas were professional skills used, overtime, perception about advancement opportunities in the job, management ratings, clarity of goals and directives.

Psychosocial indices
Specific psychosocial items were aggregated into different scales called indices. The indices were based on current psychosocial and management concepts and validated using factor analysis, predictive, and concurrent validity,
as well as relating stress scales to biological markers at the group level (see Table 1). Most indices had a Cronbach’s alpha of 0.7 or higher (Arnetz 1996). These indices measured specific psychosocial concepts.

Table 1. Indices and items used in the study

<table>
<thead>
<tr>
<th>Index</th>
<th>Index Content</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental workload</td>
<td>Demand: work tempo, effort, enough time to perform, conflicting requirements and work speed. Control: learn new things, skill requirements, repetitiveness.</td>
<td>Karasek and Theorell, Demand / Control model (1990)</td>
</tr>
<tr>
<td>Mental energy</td>
<td>Restlessness, irritability, worry, feeling low, moodiness, and difficulty concentrating.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Psychosomatic</td>
<td>Mental fatigue, headache, restlessness, irritability, moodiness and difficulty concentrating.</td>
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<tr>
<td>Mission Clarity</td>
<td>Workplace goals are well defined, realistic, influence able and assessable.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Leadership</td>
<td>Clear communication, integrity, consistent, “my manager acts as a good example”, acts with humanity, persistent, visible and flexible.</td>
<td>Ekwall &amp; Arvonen 1990 (leadership questionnaire) and questions from Ericsson Management Requirements. Arnetz (1996)</td>
</tr>
<tr>
<td>Performance feedback</td>
<td>Clarity regarding job requirements, feedback on job performance, change management information.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Participatory management</td>
<td>Influence on workplace decisions, “can you decide what to perform and how to perform”.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Skills utilization</td>
<td>Enough expertise for requirements and work demands in line with your expertise.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Social work climate</td>
<td>Atmosphere at work, cohesion and supportive atmosphere among coworkers.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Coping style regarding too high workload</td>
<td>Feel unsuccessful and self-critical, get upset and object to the situation, accept the unavoidable, try to think about something else, prepare an action plan to follow, see the situation as challenging, keep the problem to myself, look for help and support, concentrate and take one step at a time.</td>
<td>Arnetz (1996)</td>
</tr>
<tr>
<td>Type A behavior</td>
<td>Impatience, need for achievement, competitiveness, hostility and aggression.</td>
<td>(Roseman, Brand et al. 1975)</td>
</tr>
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</table>
The questionnaire had previously been validated and found to be psychometrically sound (Arnetz 1996).

Blood samples
The following biological variables were chosen:

- Serum prolactin. This variable was used as an unspecific implicator of physiological arousal (Arnetz 1996).
- Serum testosterone/estradiol. This was used as an implicator of the recovery and restoring processes. (Theorell, Karasek et al. 1990; Halford, Anderzen et al. 2003).
- Serum cortisol. This measure was used to assess long-term stress activation. (Arnetz 1996).

Blood samples were taken immediately before the start of the intervention, at the end (+3 months) and five months after the end of the formal training period (+8 months). Blood was sampled between 8 a.m. and 10 a.m. after overnight fasting. The individual time sampling differences during the three assessment periods were +/- 15 minutes to as far as possible minimize the effects of diurnal variations. The blood samples were frozen at -80 degrees Celsius for later analysis in a quality controlled, quality assured, university laboratory certified by the Swedish accreditation body (SWEDAC) complying with EN 45001, the European norm. Serum was later analyzed for serum testosterone, serum cortisol, and serum prolactin using commercially available radioimmunoassay techniques.

Data collection
Blood samples as well as questionnaires were collected three times during the study period. Data from the baseline assessment, before the introduction of the formal stress management program, was used in Paper I.

In Papers II, III, and IV data from all three assessments – before formal stress management training started (baseline), directly after the formal training ended (+3 months) and five months after the formal training ended (+8 months from the baseline assessment) – was used (see Figure 5).
Intervention techniques

In Papers III and IV three different stress management techniques were used in the intervention group. The Intervention group subjects had to choose one of these three stress-management techniques:

- Progressive relaxation, where participants learn to contract and relax different body parts progressively. (Benson, Rosner et al. 1974).
- Applied relaxation, which is a development of progressive relaxation, where subjects, besides learning to achieve a relaxed state of mind within 60-90 seconds, also learn to reduce the escalation of the psychophysiological stress response (Öst 1987).
- T’ai Chi Chuan, which is an ancient Chinese martial art where mental relaxation is obtained by concentrating on a series of controlled body movements (Sandlund and Norlander 2000).

Participants received 1-1.5 hours of weekly training at work by a skilled trainer during regular working hours, over a three-month period. The cost per person in the Progressive Relaxation program was about USD 500, in the Applied Relaxation program the cost per person was about USD 1100, and the cost per participant in the T’ai Chi program was about USD 700.

Ethical approval

The project was approved by the Ethics Committee of the Karolinska Institute (Reference Number 93:70).
Statistical analysis

All data in Papers II, III, and IV was analyzed using BMDP statistical software, 1993 PC version. For Paper I, Release 7, 1992 was used. Data were at first assessed for means, medians, dispersion measures, and possible outliers. Variables that were not normally distributed were logarithmized prior to being used. Chi-squared analysis and Student’s $t$-test for uncorrelated comparisons were used to compare the two samples. Correlations analysis between work environmental factors and the dependent indices were studied. Analysis of variance (ANOVA) was also used to compare possible differences in means between the groups over time. Linear regression and multiple regression analysis were used when testing the significance of the various explanatory models (see Table 2). Statistical significance was set to a two-tailed p-value of less than .05. For more detailed information see the respective paper.

Table 2. A summary of the statistical analyses used in each study.

<table>
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<tbody>
<tr>
<td>Means, median and dispersion analyses</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Logarithmized</td>
<td></td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>Student’s $t$-test and Chi-square</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Pearson correlation</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<tr>
<td>Linear regression analyses</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Multiple regression analyses</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Turkey’s post-hoc method</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>1-way ANOVA</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>2-way ANOVA</td>
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<td></td>
<td>X</td>
<td>X</td>
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</table>
Summary of papers

Paper I

The aim: To investigate the possible association between psychosocial and physiological factors as well as individual characteristics and musculoskeletal symptoms and headaches.

Methods: A cross-sectional study. The participants were telecommunication software designers (n=116). The subjects responded to a questionnaire regarding bodily symptoms, psychosocial work environment, and socio-economic status. Blood tests were taken as well. The blood samples were analyzed for serum testosterone, serum cortisol and serum prolactin.

Result: A significant correlation was found between psychosocial work environmental factors, i.e. workload, perceived lack of skills, competence for one’s job, and lower arm symptoms. Furthermore the ratio between job autonomy and workload correlated with lower arm symptoms, i.e. those with higher autonomy related to the workload reported fewer symptoms. Dissatisfaction with one’s superior, younger age, conflicts between family and work and lower testosterone values correlated with neck and back symptoms. Lower ratings of work satisfaction correlated significantly with headaches. A significant correlation was found between, on the one hand, musculoskeletal symptoms and headaches and, on the other hand, lower levels of circulation testosterone.

Conclusion: A lower-rated psychosocial work environment is associated with biological markers. It is possible that part of the musculoskeletal symptoms and headaches found in high tech work environments might be mediated via neuroendocrine mechanisms. However this was a cross-sectional study and the results need to be replicated using a longitudinal study design.
Paper II


The aim: To investigate the possible association between psychosocial factors in a high tech working environment and psychosomatic symptoms i.e. mental fatigue, headache, restlessness, irritation, moodiness, and difficulty concentrating.

Methods: A prospective longitudinal study. A psychosomatic index comprising mental fatigue, headache, restlessness, irritation, moodiness, and difficulty concentrating was developed in order to study the above-mentioned symptoms in advanced telecommunication software designer. The participants in this study were 135 persons from two different departments at a telecommunication design company. The psychosocial work environment was measured with a standardized questionnaire. Biological measurements, i.e. serum testosterone, serum cortisol, and serum prolactin, were taken as well.

Result: The increase in perceived workload correlated with increased ratings on the psychosomatic index during the 8-month study period. Significant predictors of changes in the psychosomatic index were worsening collegial support at work and increased workload.

Conclusion: There is an indication that psychophysiological activation is rather common among telecommunication software and system designers. The higher the perceived work stress level, the higher the reported cognitive psychosomatic stress level was. An increased workload and decreased collegial support seemed to be risk factors for reporting psychosomatic symptoms.

Paper III


Aim: A longitudinal study investigating the possible long-term effects of a structured stress management programs on skin symptoms, and determining the possible mediating role of stress hormones in linking stress to skin symptoms.
Methods: The subjects were telecommunications software and systems design engineers (N=116). In order to measure possible changes in the biological markers, blood samples were taken for serum testosterone, serum cortisol, and serum prolactin. Furthermore a comprehensive questionnaire regarding the psychosocial environment including questions of skin symptoms was produced. All assessments were collected three times during the study period. The first assessment was done before the intervention started, the second one after three months, directly after the intervention program was finished, and the third assessment was conducted five months after the formal end of the training (the follow-up assessment). Half of the subjects participated in one of the three stress management programs (N=66), while the other half functioned as a reference group (N=50).

Results: The prevalence of skin symptoms was 29% in the first assessment for the total study group. The intervention group decreased their skin symptom index significantly with an average of 0.89 points between the first and the second measurements. The skin complaints for the reference group did not change between the first and the second assessments. There were no residual beneficial effects five months after the formal training ended. Between the first and the third assessments there was a significant increase in self-reported workload in the reference group as compared to almost unchanged levels in the intervention group.

Conclusion: Unspecified skin symptoms seemed to be common in this study population. During the active training period the intervention group decreased their skin symptoms compared to the reference group. However no residual benefits existed five months after the formal training was finished. It is possible that stress management could be a tool for the individual to decrease unspecified skin symptoms during stressful work periods.

Paper IV


Aim: A prospective longitudinal intervention study. The aims of this study were to investigate the possible impact on neck and back, lower arm and headache respectively, from structured stress management programs, and to determine the possible mediating role of stress hormones in linking stress and symptoms.
Methods: The subjects were telecommunications software and systems design engineers (N=116). Participants responded to a comprehensive questionnaire concerning their psychosocial work environments and possible musculoskeletal symptoms. Blood samples, i.e. serum testosterone, serum cortisol, and serum prolactin, were collected as well in order to measure possible changes in the selected biological markers. Three measurements were conducted during the study period. The first assessment was done before the intervention started, the second one after three months, directly after the intervention program was finished, and the third assessment was conducted five months after the formal end of the training (the follow-up assessment). Half of the subjects participated in one of three stress management programs (N=66), while the other half functioned as a reference group (N=50).

Results: During the active training period there was a significant difference between the groups in lower arm symptoms. The reference group increased their symptoms while the intervention group did not change. Initial levels of testosterone and stress management were significant predictors for changes in lower arm symptoms. No remaining effects were seen five months after the intervention. Changes in serum testosterone did not correlate with changes in symptoms. No effects were seen on neck and back symptoms or on headache.

Conclusion: This study suggests that stress management interventions have a limited favorable impact on lower arm symptoms during the active training period. The type of intervention program did not significantly affect overall results regarding lower arm symptoms. This indicates that any method that teaches employees to wind down mentally might be beneficial. From a cost-benefit perspective, applied relaxation – the most costly method used – did not have additional benefits on musculoskeletal symptoms. Therefore, we suggest that simple stress management methods should be the methods of choice.
Summary of the hypotheses testing

The results of the hypothesis testing are presented in Table 3. More detailed information is presented in the individual papers.

Table 3. The results of the overall hypothesis testing

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Results of testing</th>
<th>Paper</th>
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<tbody>
<tr>
<td>Psychosocial work environmental factors covary with neck, shoulder, arm,</td>
<td>Our findings support this hypothesis, i.e. psychosocial work environmental factors covaries with neck, back, and skin symptoms as well as with headache. Confirmed</td>
<td>Paper I</td>
</tr>
<tr>
<td>and skin symptoms as well as with headache.</td>
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<tr>
<td>Biological factors i.e. serum testosterone is associated with musculoskel-</td>
<td>A significant predictor of decreased symptoms in the lower arm was higher initial testosterone levels. Those with lower levels of circulating testosterone reported more neck and back symptoms as well as headache. No association was found with regard to serum testosterone and skin symptoms. Partly confirmed</td>
<td>Paper I and Paper III</td>
</tr>
<tr>
<td>etal symptoms, headaches, and skin symptoms.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological factors e.g. serum prolactin are associated with skin symptoms,</td>
<td>Changes in serum prolactin did not significantly correlate to changes in skin symptoms. Rejected</td>
<td>Paper IV</td>
</tr>
<tr>
<td>i.e. the higher the levels, the more reported symptoms.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological factors e.g. serum cortisol are associated with musculoskeletal</td>
<td>No significant changes were found between serum cortisol and symptoms. Rejected</td>
<td>Paper I and Paper III</td>
</tr>
<tr>
<td>symptoms, headache, and skin symptoms, i.e. the higher the levels, the</td>
<td></td>
<td>and IV</td>
</tr>
<tr>
<td>more reported symptoms.</td>
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</table>
Psychosocial work environmental factors are associated with psychosomatic symptoms i.e. mental fatigue, headache, restlessness, irritation, moodiness and difficulty concentrating.

Our findings suggest that a perceived increased mental workload as well as worsening collegial support correlate with an increase in the psychosomatic index.

**Confirmed**

**Paper II**

Stress management intervention programs have an impact on biological markers.

Serum prolactin decreased in the intervention group compared to the reference group during the study period.

**Confirmed**

**Paper III and Paper IV**

Serum testosterone increased significantly during the actual training period in the intervention group compared to the reference group.

*These findings are reported by B.Arnetz.*

**Arnetz (1996.)**

Stress management is inversely associated with musculoskeletal symptoms in the neck and back as well as with lower arm, headache and with skin symptoms.

The stress management intervention had a limited favorable impact on lower arm and skin symptoms during the study period.

(Short term effects).

**Partly confirmed**

**Paper III and Paper IV**

Stress management intervention programs are associated with a favorable impact on the psychosocial work environment.

There were no significant associations between stress management and the perceived psychosocial work environment.

**Rejected**

**Paper III**
General Discussion

Aims and hypothesis

The purpose of this thesis was to identify risk and protective factors for musculoskeletal and skin symptoms, and for headache, among software and system design engineers in a high tech work environment. We also wanted to identify their possible association with work stress. An additional purpose was to evaluate the possible short-term and long-term benefits from structured stress management programs on musculoskeletal symptoms from the neck and back as well as on skin problems and headache. As stress in the work environment might be a contributor to the ill-health symptoms mentioned above, the association between biological factors, i.e. stress-sensitive hormones and changes in musculoskeletal symptoms, skin symptoms, and headache were monitored in longitudinal studies, i.e. a stress management intervention program. Moreover we studied the possible association between psychosocial work environmental factors and a psychosomatic index based on the following factors: mental fatigue, headache, restlessness, irritation, moodiness and difficulties concentrating. Finally, we wanted to evaluate the possible impact of stress management intervention programs on the perceptions of the psychosocial work environment.

The principal findings in this thesis were:

- A significant correlation was found in the cross-sectional study between psychosocial work environmental factors, and musculoskeletal symptoms and headache.
- There was an association between lower levels of serum testosterone and a higher frequency of musculoskeletal symptoms and headache.
- The stress management intervention program had a short-term favorable impact on skin symptoms and lower arm symptoms.
- There was a significant inverse correlation between changes in collegial support at work and increased psychosomatic symptoms as well as with increased mental workload and psychosomatic symptoms.
- Younger age and years with computer work seemed to be predictors for musculoskeletal symptoms.
Our findings regarding risk factors for musculoskeletal symptoms as well as headache are partly in line with what other authors have found (Estlander, Takala et al. 1998; Bongers, Kremer et al. 2002; Cho, Hwang et al. 2003; Bystrom, Hanse et al. 2004). Significant risk factors for neck and back in our study were dissatisfaction with one’s line manager, lower levels of serum testosterone, and conflicts between family and work, as well as younger age. An association between lower testosterone levels and musculoskeletal disorders in women has been reported by Kaergaard (2000) and by Finset (2004). However, in neither of these studies was any association found between changes in testosterone levels and changes in musculoskeletal symptoms.

Poor skills utilization, the ratio between autonomy and workload (less autonomy), and years of computer work as well as younger age seemed to increase the risk for lower arm symptoms. Competence and skills utilization is considered to be a part of control in one’s work, according to the demand-control model (Karasek and Theorell 1990). However, competence or skill utilization is not included in the analysis where the outcome measure is decision latitude. It is possible that the demand-control model needs to be further developed with regard to competence matters and skill utilization. This matter has also been noticed by Widmark (2005) in her stress research report.

These findings are interesting from a modern working life perspective, where the requirements on employee’s skills and knowledge are increasing. To possess more skills and competence than one can use in one’s work might be a contributor to work-related symptoms in the musculoskeletal system.

Age seemed in our study to be associated with musculoskeletal symptoms, i.e. subjects of younger age reported more symptoms. This was not expected, however similar findings have been reported in later research (Tvermo, Dalgard et al. 2003; Norman, Nilsson et al. 2004). According to Soares (2003) older and younger subjects experience their pain differently. Younger persons seemed to report more severe pain than older. It might also be possible that younger persons tend to report more symptoms, or they might have worse health than the older persons in this regard. It is not excluded that our findings might be a result of the healthy workers effect.

Conflicts between family and work seemed to be a predictor for neck and back symptoms. Family related stress has been reported by Orth (2001) to be a risk factor for cardiovascular disease in women. The majority of our study population consisted of males. It is possible that men today to some extent experience the conflicting situations between work and family as a stressor which might contribute to musculoskeletal symptoms.

Lower ratings of work satisfaction and lower levels of serum testosterone seemed to be risk factors for higher frequency of headache. It is possible that poor work satisfaction affects the HPG axis, resulting in decreased testosterone values and thereby a modifier for headache. However, Leone reported in his literature review (1993) regarding hormones and cluster headaches, that
the variety and complexity of neuroendocrinological changes are hard to interpret. The author suggested that the induced testosterone values are probably due to the pain.

Skin symptoms seemed to be a more commonly reported health issue than musculoskeletal symptoms in this population. During the actual stress management training a significant decrease in skin symptoms as well as in serum prolactin values was found, compared to the reference group. Berg (1992) reported similar findings in a case control study on VDU-related skin symptoms, where cases had a higher level of circulating prolactin and lower levels of serum testosterone during working time, compared to during leisure time. However, there was no association in the intervention study between changes in skin symptoms and changes in serum prolactin values. The only significant predictor for a decrease in skin symptoms was to be part of the intervention group.

Stress management as a concept consists of a multitude of different interventions and techniques. Stress management, i.e. relaxation training, has been offered in its different forms to patients with cardiovascular disease, to patients with depression and anxiety, as well as to subjects with stress-related symptoms. The common goals of most of these interventions have been to improve the coping ability, increase self-confidence, and learn how to reduce the effects of stressful situations in order to obtain beneficial results on the studied ill-health symptoms. A literature review (Öst 1987) regarding applied relaxation concluded that this technique was more effective for phobia and anxiety than no intervention at all. Our findings support the results of other authors (Hasson, Arnetz et al. 2004) who have reported that stress management seems to have an impact on pain during active training but the long-term effects are poor. According to our results, the type of stress management and the amount of training sessions an individual underwent was of less importance; the main issue was to be part of an intervention group. However, our findings were not fully in line with results from other authors where the duration of training seemed to be more important than the program itself (Carlson and Hoyle 1993).

Stress management seemed to have an effect on the perceived mental workload. However, subjects in the intervention group reported unchanged levels of mental load while the reference group reported increased levels during the same time period. The actual workload increased equally in both groups during the study period. These findings might be of importance considering that an increasing mental workload was associated with higher psychosomatic scores, indicating an increase in psychosomatic symptoms.

Stress management had no beneficial effects on headaches. However our findings were not in line with those of Nash (2003), which show that relaxation training, as an alternative to pharmaceutical treatment, was effective on tension-type headache.
Possible mechanisms that might explain why stress management is effective in combating musculoskeletal and skin symptoms during active training are: a) a decrease in the activation of the sympathetic system, resulting in an increased blood flow in the muscles and a normalized muscle metabolism, and b) effects of neuronal plasticity (McEwen 2001). Neuronal plasticity might be hampered by long-lasting pain or stress. The capacity, structure, or function of the neurons might change, e.g. by decreased or increased sensitivity to stimulus. Two kinds of plasticity regarding pain and hypersensitivity have been discussed; these include modulation and modification, resulting either in more neurons in order to respond to a decreased sensitivity, or in an enlarged response. These plastic changes are affected by physiological factors. It is possible that subjects during active stress management, via inhibition of the sympathetic system and via an activation of the parasympathetic system recreate the capacity, function or structures of the neurons in the CNS. It is also possible that the duration and intensity of active training was too low or that three months is much too short a time for the long-term re-establishment of the neural plasticity.

Methodological considerations
Weaknesses & Strengths
There are a number of methodological issues that were not optimal in the different studies. A weakness in Studies III and IV was that the subjects could choose one of the three stress management programs instead of being randomized to a specific program. The reason for this was to ensure that participants could choose among quite different techniques, demanding varying degree of time and commitment. This was believed to encourage higher participation rate. However the main approach in this paper was to evaluate the whole intervention group and not to compare techniques. This design might have biased the result, considering that the most interested and motivated employees enrolled in the stress management intervention program. However, taking into account that this intervention was conducted during working hours in an organization with a high project pressure, the participation rate might not be considered low. Hunt et al. (2005) have published results regarding workplace interventions with participation rates of 20%. The dropout rate from the intervention programs was low and compliance was more than 90%. The intervention study had a longitudinal design which allows us to more reliably discuss possible causal association between exposures and outcome factors of interests.

The regression towards the mean (RTM) is a statistical phenomenon that needs to be taken into consideration when one interprets the study results (Morton and Torgerson 2005). Briefly, this phenomenon can be described as
a movement towards the mean, where high values decrease and low values increase, which might affect the true value. Our intervention study used a reference group, which might have overcome the effects of RTM.

Furthermore, no differences were found between the genders regarding the results. Twenty-one percent of the participants were females, but their menstrual cycles were not taken into consideration during data collection. The amount of females in the study was relatively few and this matter is not assumed to bias the final result.

The measured symptoms were self-reported and not diagnosed by clinical examinations. This might result in an over- or underestimation of symptoms. However, Ottosson et al. (1994) have reported that self-rated musculoskeletal disorders from neck, shoulder, and upper extremities are fairly in line with clinically diagnosed disorders. However, Toomingas (1995) reported an overestimation of self-reported symptoms compared to findings from physical examination.

The data collection was conducted during different seasons. It is possible that the seasonal variations had an impact on both self-reported symptoms as well as biological markers. However no assessment was conducted directly after longer holidays.

It is possible that the blood sampling procedures of the measured hormones were not sensitive enough to detect long-lasting effects from the interventions. For instance, cortisol has a considerable daily variation cycle and the test results from a stress point of view should be done with greatest caution. It is most likely that the cortisol levels taken both in saliva and serum depicts individual secretion patterns and does not give information on whether the levels are high or low. Prolactin is a fast-reacting hormone that has been considered to be stress-sensitive. It is possible that the hormone’s short half-life contributes to the limited findings in our studies. Prolactin is also sensible to other stimuli such as smoking, estradiol, and food intake.

Due to the number of dependent measures used in the analysis there is a risk for Type 1 error, meaning that some of the significant psychosocial factors reached the correct critical significance level without being statistically significant. Therefore the interpretation of each ANOVA should be made with caution. However, the overall pattern in our results is in line with predicted results, i.e. our hypotheses.

Result application and future research.

Psychosocial work environmental factors are of increasing importance in the organization of healthy and productive workplaces. They ought to be permanently on the agenda in the work environmental efforts that are made by the management and the unions. Psychosocial work environmental goals should be as important as production and economical goals at the company level,
with deployment and follow-up further down in the organization. To regularly measure the mental workload and to take corrective actions when needed might decrease the psychosomatic symptoms in the organization. Furthermore, stress management designed as relaxation and mental training might be a tool to use for the organization during stressful periods in order to diminish skin and lower arm symptoms among well-educated technicians working with software and system design.

It is obvious that stress management interventions are only one brick in the large and time-consuming work of reducing ill-health symptoms in an organization. Several authors have reported the importance of organizational improvement issues in order to prevent and diminish physical ill-health at the workplace (Melin, Lundberg et al. 1999; Anderzen and Arnetz 2005).

In order to better understand the association between psycho-physiological factors and musculoskeletal and skin symptoms, more prospective studies need to be conducted. Additional studies regarding eyestrain and its possible association with headaches in increasingly computerized work environments should also be taken into consideration in future interventions. It would be of particular interest to further study possible psychosocial work environmental factors and the impact on musculoskeletal symptoms as well as on skin symptoms and headache in modern working life and their possible associations with efficiency and productivity.
Conclusion

The results of these studies suggest that accurate and sufficient competence and skills utilization are of importance, not only from a company business aspect, but also from a well-being perspective. The gap between one’s perceived competence and the actual competence utilization seemed to be a predictor for musculoskeletal symptoms in the lower arm. It is possible that the theories regarding work demands and perceived autonomy in one’s work during times of major organizational changes, combined with an increasing workload, are not fully applicable to describing work stress in a technical development work environment. Psychosocial factors were associated with stress-sensitive hormones, while some stress-sensitive hormones were associated with musculoskeletal and skin symptoms as well as with headaches. The results of these four studies suggest that stress, aroused during challenging technical development, resulted in a physiological activation. The physiological activation reflected changes in circulating levels of stress-sensitive hormones and musculoskeletal and skin symptoms as well as headaches. Furthermore, stress management, conducted as a structured mental and muscular relaxation training program had short term – but no long term – stress- and symptom-releasing effects. These kinds of programs might be useful as individual stress- and symptom-reducing tools during especially stressful periods in an organization. It is very important to focus on organizational stress management interventions in order to support the necessary rapid changes in work that are a reality for most competitive development organizations of today. We also suggest more research on how competence and competence/skills utilization correlate, from a company vision and mission perspective, with changes in the work-related ill-health panorama.

This thesis contributes new understanding of occupational health challenges facing the growing, but under-researched, group of advanced knowledge workers. Since they make up an increasing proportion of employees, and are typically among the first to face new work habits and technologies, a better understanding of their occupational health and exposures might enhance our capacity for preventive actions, before the rest of the workforce starts using these new tools.
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