Work conditions, musculoskeletal disorders and productivity of dentists in public dental care in Sweden

Are dentists working smarter instead of harder?

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ABSTRACT

Introduction
During the last 20 years, Sweden and other countries have been adjusting their models of welfare to a changed economic environment. Rationalization, influenced by New Public Management, has been implemented in public dentistry in order to improve efficiency and to streamline activities. This has involved transferring some of dentists’ tasks to dental hygienists and dental nurses. The goal is to achieve a more efficient mix of skills and more interaction between professional groups, in order to utilize all skills better in a more efficient work organization. Organizational changes may have an effect on the work environment both with regard to physical and to psychosocial work conditions and affect health and well-being. In many cases these changes have a profound negative effect on musculoskeletal and mental health, and corresponding risk factors, by reducing the number of natural breaks and thus reducing the efficacy of targeted ergonomic interventions. Dentists in Jönköping County in Sweden perceive high precision demands and poor working postures in their work. The five studies in this thesis describe organizational changes and analyse the risk of illness among dentists in the public sector in Jönköping County.

Aim
The main aim is to study dentists’ physical and psychosocial work conditions and investigate associations with musculoskeletal disorders, work ability and sick leave during a period of extensive rationalizations; secondly, to assess the risk of illness as a basis for recommending preventive measures.

Methods
The present thesis was designed with four cross-sectional studies (Paper I-IV) and one prospective longitudinal study (Paper V). In Paper I, a questionnaire concerning physical and psychosocial work conditions and health was sent out to all employees working in public dental care in Jönköping County in Sweden. To obtain more information on the difficult physical work situation for dentists (Paper I), an observation study with Portable Ergonomic Observation (Paper II) and an sEMG study (Paper III) was then conducted. Paper IV deals with psychosocial issues (using the same survey as in Paper I) and questions in the Eysenck Personality Questionnaire (EPQ) and the Marlowe-Crown scale SD (MCSD), to analyse their impact on perceived physical load. In Paper V, data about physical and psychosocial
conditions and health from a survey, as well as production data (number of adult treatments per year per dentist) from computerized patient records (T4), are analysed with regard to changes and associations during a period of extensive rationalizations (2003 – 2008).

Results

In Paper I, dentists reported the poorest physical work conditions of all occupational groups and high prevalence of musculoskeletal disorders. However, relatively low intensity of pain was reported and only a small proportion thought that work was affected. Paper II and Paper III confirmed that dentists’ work is physically demanding, with sitting postures and head bent forward, as well as prolonged low muscle loading. Paper IV shows that physical load is mainly influenced by psychosocial demands and to some extent by loss of work control. The results in Paper V show that during the period of extensive rationalizations between 2003 and 2008, dentists perceive improved precision demands and fewer uncomfortable work postures, but still a high level of physical load. The number of adults treated per dentist also improved, but there was a slight deterioration in work control and leadership.

Conclusions

The results in this thesis show a consistent picture of high perceived physical load due to high precision demands and uncomfortable work postures, supported by observation of body movements (Portable Ergonomic Observation) and sEMG signs during psychosocially demanding circumstances. The rationalizations implemented in Jönköping County during the period 2003-2008 have not resulted in a deterioration of the physical environment, in spite of the fact that dentists produce more treatments of adult patients than before. This result may indicate that rationalizations do not always lead to increased health risks; it depends how they are implemented. Dentists may have changed the way they work for the better, and due to task delegation and SMS reminders a smoother patient flow has probably resulting in a reduction of workload and perceived stress regarding financial loss.
SAMMANFATTNING

Bakgrund

Under de senaste 20 åren har Sverige och andra länder anpassat sina välfärdsmodeller till de förändrade ekonomiska förutsättningarna. Rationaliseringar influerade av New Public Management har genomförts i den offentliga tandvården i syfte att förbättra effektiviteten i verksamheten. Rationaliseringar har omfattat överföring av en del tandläkare uppgifter till tandhygienister och tandläkare. Målet är att åstadkomma en effektivare blandning av kunskap och mer samverkan mellan yrkesgrupper för att uppnå en mer effektiv arbetsorganisation. Organisatoriska förändringar kan påverka arbetsmiljön både med avseende på fysiska och psykosociala arbetsförhållanden och påverkar hälsa och välbefinnande. Dessa ändringar har många gånger mycket negativa återverkningar på muskuloskeletala och psykisk hälsa genant att minska antalet naturliga avbrott och därmed minska effekten av riktade ergonomiska insatser. Tandläkare i Jönköpings län i Sverige upplevde höga precisionskrav och dåliga arbetsställningar i sitt arbete. De fem studierna i denna avhandling beskriver organisatoriska förändringar och analyserar risken för sjukdom bland offentligt anställda tandläkare i Jönköpings län.

Syfte

Huvudsyftet är att studera tandläkares fysiska och psykosociala arbetsförhållanden och relationen med muskuloskeletala besvär, arbetsförmåga och sjukskrivning under en period av omfattande rationaliseringar, samt att bedöma risken för sjukdom som grund för rekommendationer om förebyggande åtgärder.

Metod

produktion (mätt som antalet vuxna behandlingar under ett år per tandläkare) från de datoriserade journalerna (T4) under en period av omfattande rationaliserings mellan år 2003 till 2008.

**Resultat**


**Slutsatser**

Avhandlingen visar ett tydligt resultat av hög upplevd fysisk belastning på grund av höga precisionskrav och obekväma arbetsställningar under psykosocialt krävande omständigheter. Detta stöds av andra metoder som Portabel Ergonomisk Observation (PEO) och yt-elektromyografi (sEMG). De genomförda rationaliseringsarna i Jönköpings län under perioden mellan 2003 och 2008 har inte försämrat den fysiska miljön trots att tandläkarna producerar mer behandlingar av vuxna patienter än tidigare. Detta resultat kan tyda på att rationaliserings inte alltid leder till ökade hälsorisker, men är beroende av hur genomförandet utförs. Tandläkarna kan ha ändrat på det sätt de arbetar till det bättre och delegering av arbetsuppgifter och SMS-påminnelser innebär troligtvis ett större och jämnare patientflöde med minskad arbetsbelastning och därmed också minskad upplevd stress för ett sämre ekonomiskt utfall.
LIST OF PAPERS


IV. Rolander,B; Stenström, U; Jonker, D. Relationships between psychosocial work environmental factors, personality, physical work demands and workload in a group of Swedish dentists, Swedish Dental Journal, 2008;32:197-203.

V. Rolander,B; Jonker, D; Balogh, I; Sandsjö,L; Winkel,J; Svensson,E; Ekberg,K. Working conditions, health and productivity among dentists – a prospective study during rationalization in public dental care. In manuscript.
ABBREVIATIONS

ARV       Average Rectified Value
CFI       Comparative Fit Index
CTS       Carpal Tunnel Syndrome
EPQ       Eysenck Personality Questionnaire
MCSD      Marlowe-Crown SD scale
MPF       Mean Power Frequency
MVC       Maximum Voluntary Contraction
NPM       New Public Management
PEO       Portable Ergonomic Observation
RMR       Root Mean square Residual
RMSEA     Root Mean Square Error of Approximation
RVE       Reference Voluntary Electrical activation
SEM       Structural Equation Modelling
SOU       Swedish National Public Investigations
sEMG      Surface Electromyography
WMSD      Work-related MusculoSkeletal Disorders
INTRODUCTION

Rationale for the thesis

In 1996, the dental management in Jönköping County asked the Occupational Health Care Service to evaluate the work conditions of employees, with special focus on those working in public dental care who had work-related symptoms. The results showed high perceived physical workload among dentists and possibly increased risk of muscular disorders. This was the starting point for a series of studies on dental work conditions and health. In this thesis a particular interest lies in whether organizational and technological changes over time in public dentistry influence work conditions and the risk of musculoskeletal disorders, work ability and sick leave. The dental profession in Jönköping County was selected as the empirical basis for the studies.

Occupational healthcare in Sweden has existed for many years and has the task of monitoring and attending to employees’ work environment to reduce the risk of work-related illness. The thesis aims to increase knowledge about the work environment from both an organizational and individual perspective as a basis for risk prevention and reduced sickness among dentists, and thus reduced productivity in public dental clinics.

Organizational and technological conditions

During the last 20 years, Sweden and other countries have been adjusting their models of welfare to a new/changed economic environment. In the public sector reforms are generally known as “New Public Management” (NPM). This strategy is influenced by lean production developed from the basic elements of Taylorism and behavioural science theories. New Public Management (NPM) in the public sector is based on a cluster of ideas that are borrowed from the business community and the private business practices that govern organizations. The exact reforms are for instance the introduction of explicit measures of performance, decentralization, introduction of private-sector styles of management, contracting out, privatization and focus on service and client orientation (Clark, 2000).

Rationalization influenced by New Public Management (Almqvist, 2006b) has been implemented in public dentistry in order to improve efficiency and streamline activities (Harrisson et al., 1990, Hasselbladh, 2001). Rationalization is defined as “the methods of technique and organisation designed to secure the minimum of waste of either effort or
Rationalizations are often influenced by lean perspectives also in public organizations by e.g. intensification, standardization of processes and performance measurements (Brödner and Forslin, 2002, Westgaard and Winkel, 2010). Rationalizations may also involve changes in work tasks. In public dentistry, this has for example involved transferring some dentists’ tasks to dental hygienists and dental nurses. The goal, as stated in a government report, is to achieve a more efficient mix of skills and more interaction between professional groups in order to utilize all skills better in a more efficient work organization (SOU, 2002). Technology is another important feature of rationalizations and may be a tool for the employees, but may also involve management work control of employees (Bejerot, 1998).

**Effects of rationalizations on work conditions**

Recent research highlights the importance of assessing the association between organizational principles and technological development, and physical and psychosocial work conditions. Bejerot (1998) suggested that technological and organizational changes since the 1960s may contribute to a strenuous work situation for dentists. At the physical level, rationalizations may lead to lack of variation in load pattern, and long hours in the same sitting position (Wells et al., 2007), and (Westgaard and Winkel, 1996) found that, in spite of better workplace design, rationalizations could lead to increased risk of musculoskeletal disorders. Similar results have been found for dentists (Bejerot, 1998, Brödner and Forslin, 2002). However, some studies suggest that rationalizations involving improved productivity and reduced time due to losses do not automatically result in higher workload and increased worker’s risk of WMSD injuries (Christmansson et al., 2002, Womack et al., 2009).

Research on the effects of rationalizations on the psychosocial work environment is still limited. Rationalizations involve changed demands on how leadership is performed (Vest and Gamm, 2009), rearrangement of work procedures, work intensification and changed temporal exposure factors, adapted equipment, and changes in the work environment (Marras et al., 2009). Some studies have been performed in the car industry with the aim of investigating the stress effects of lean production. The results are divergent. In a study of 21 worksites in four industrial sectors in the UK, Conti et al. (2006) report a non-linear response of stress to lean
implementation. Their results indicate that lean production per se is not stressful, but management decisions regarding how lean production is designed and performed affects opportunities for stress control among employees (ibid). Noblet and Rodwell (2008) suggest that stress associated with NPM may largely be prevented by “managers ensuring that employees have adequate levels of support from supervisors and colleagues and making sure that employees’ level of job control is commensurate with the pace, volume and complexity of demands they face” (Noblet and Rodwell, 2008). These studies thus indicate that rationalizations per se may not be detrimental to employees’ work conditions, but the implementation process and management performance during organizational changes are crucial for how effects evolve.

Kristensen (2010) concluded in a systematic review that improved work conditions affect production and quality of work. In the implementation of rationalizations there may be a conflict between the aims of rationalization and the aims of work environment improvement (Landsbergis et al., 1999a), for example with regard to aspects of time, such as allowing less opportunity for breaks and recovery for the employee. In a review of studies on the effects of rationalizations on musculoskeletal and mental health, Westgaard and Winkel (2010) found that during rationalizations are issues concerning group autonomy, worker participation in terms of team responsibility and resonant management style with goal clarity, transparency and dialogue, modifiers with a positive influence on worker health.

Important in this context are also information about the rationalizations process, that support from co-workers and superiors is both informal and non-specific, and issues about procedural justice, for example fair treatment. These aspects may be considered important indicators of the psychosocial conditions at the workplace.

Thus, the results of (Westgaard and Winkel, 2010, Noblet and Rodwell, 2008, Kristensen, 2010), suggest that the effect rationalizations have on the work environment is not only a matter of physical demands or mental demands, but to a significant degree also a matter of the psychosocial consequences of how rationalizations and other changes are implemented in the organization, how leadership is performed and what opportunities there are for social support.
Rationalizations, health and production

A sustainable work system implies that there is a balance between efficiency at work and the risk of developing health problems (Docherty et al., 2002). As organizational changes may have an effect on the work environment with regard both to physical and psychosocial work conditions, they may also affect health and well-being. Westgaard and Vinkel (2010) found in a recent systematic review that rationalizations have a profound, negative effect on musculoskeletal and mental health. The most negative effects were found for downsizing and restructuring rationalizations in general. In their review, the health sector was found to be especially affected.

Recent research points to the importance of including both sickness absence and sickness presenteeism (Aronsson et al., 2000, Schultz and Edington, 2007) as important measures in studies of effects of organizational and work environment factors on production. Van den Heuvel (2007) showed that productivity losses were mainly due to sickness presenteeism among workers with upper extremity problems. In a later study, (van den Heuvel et al., 2010) conclude that among work-related factors, psychosocial work conditions have the strongest relation to productivity loss.

Work environment

Dentists’ physical work environment

Today, most dentists work with the patient seated in a reclining position. From chair side and with the continuous assistance of a dental nurse, “four-handed” dentistry is usually practiced. The dentist is usually on the right of the patient and the dental nurse on the left. High- and low-speed hand pieces, ultrasonic scalers and water and air syringes are usually placed on a platform over the patient’s chest, while the suction equipment is on the left side. Hand tools are on a movable tray that can be placed in front of, alongside or behind the patient, as needed. The work is usually carried out while seated, with elevated and unsupported arms, frequently away from the body, e.g. when reaching for an instrument at arm’s length. The requirements of vision and accuracy in the work cause forward bends and rotated positions of the body. The patient’s mouth is a small surgical area where the dentist has to handle a variety of tools, while simultaneously having a good general view (Åkesson, 2000).
Physical and psychosocial risk factors

Physical load, prolonged abnormal posture and repetition are risk factors which may contribute to musculoskeletal disorders (Nordander et al., 2009, Walker-Bone and Cooper, 2005, Yamalik, 2007). However, the picture is ambiguous with regard to the relationship between physical load and increased risk of musculoskeletal disorders. Some extensive review studies indicate uncertainty concerning the relation between physical workload and musculoskeletal disorders for the neck, but not for other parts of the body such as the shoulders (Bernad, 1997, National Research Council (NRC) and the Institute of Medicine, 2001, Sluiter et al., 2001). The relationship is not clear due in part to the fact that the work environment is multifactorial with many mutual relationships that may interact in different ways.

Several studies show that dentistry is physically demanding (Jonker et al., 2009, Akesson et al., 1997, Finsen et al., 1998). Studies also show an increased risk of symptoms from the musculoskeletal system due to biomechanical load (Alexopoulos et al., 2004), dentists’ long working hours in the course of a day (Szymanska, 2002), the combination of static posture, repetitive movements, poor positioning, workplace design, and mental stress predisposition; but genetic factors, physical condition, age or non-work activities are also risk factors. Back problems and musculoskeletal pain are in some cases directly attributed to specific clinical tasks such as crown- and bridge tasks, scaling, root planning, operation of hand pieces and other power tools, involving very controlled fast motions and excessive upper body immobility (Yamalik, 2007).

Several studies show that dentists experience prolonged strain in the trapezius muscle, (Akesson et al., 1997, Finsen et al., 1998, Öberg et al., 1994) and the extensor-carpi-radialis muscle of the dominant hand (Milerad et al., 1991). Dentists sit with their heads bent forward in constrained positions for long periods, which coincides with their perception of high physical load at work (Jonker et al., 2009, Finsen et al., 1998, Akesson et al., 1997).

In Jönköping County, different occupational groups have responded to a web questionnaire including questions on work conditions during the years 1992 to 2008. Dentists in general rate their physical work conditions as very demanding compared with other professions in the county council (Figure 1, Annex 1 and 2).
Figure 1. Percentage who estimated demanding work posture over five on a scale with eleven boxes, in which "Not at all" and "Greatly" are end points. Red bars represent public and private dentists, orange bars refer to other dental employees and yellow bars represent other professions in Jönköping County during 1992-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of comparing with other professions (n = 2816, unpublished material, Rolander 2010).
Dentists’ work has also been shown to be psychosocially demanding (Bejerot, 1998). Many studies over time have considered that the aetiology of musculoskeletal disorders is complex and that both psychosocial and physical influences may be important (Ahlberg-Hulten et al., 1995, Aronsson et al., 1992, Feyer et al., 1992, Hagberg and Kuorinka, 1995, Walker-Bone and Cooper, 2005).

Psychosocial stressors in the work environment have been found to cause increased and sustained muscle activation at work (Westgaard, 1999). Factors that cause stress include lack of job variety, low job control, job strain, high job demands, workload duration, pressure and financial constraints, which may also contribute to low job satisfaction. The most stressful factor among dentists was suggested by (Wilson et al., 1998) to be time management. Hansson et al. (2001) found associations between lack of work satisfaction and musculoskeletal complaints, while psychosocial demands, work control and social support were not associated with musculoskeletal complaints in their study. Thus it may be concluded that associations between musculoskeletal health and psychosocial work conditions are unclear (Bongers et al., 2006).

Several studies have found an association between high perceived workload and experience of low support. A mix of psychosocial workplace factors, such as high psychosocial work demands, low levels of social support and a feeling of having very limited control over one’s work situation, may increase the experience of having a heavy workload and high physical demands (Karasek. R 1990, Lavoie-Tremblay et al., 2008, Roquelaure et al., 2009).

The experience of psychosocial demands at work is affected by economic structures and partly by a desire to carry out good treatment and meet patient needs (Bejerot, 1998). Social support is an important positive part of dental work, which is highly dependent on the size of the clinic, work organization, structure and work culture. Dentists in the public dental service feel appreciated by colleagues, patients and local managers, but not by their employers, according to (Bejerot, 1998). Personal characteristics may affect how psychosocial factors are experienced (Yamalik, 2007). There are, for example, gender differences in how social support is perceived; women perceive more emotional support, while men perceive more practical support (Berthelsen et al., 2008).
In a web questionnaire (2001-2008) in Jönköping County, psychosocial work demands were perceived as higher among dentists compared with other healthcare professions (Figure 2).

For social support, the picture is more mixed compared with other professions (Annex 2), and work control also shows a mixed picture. Private dentists perceive better control than public dentists (Annex 3).

![Figure 2. Percentage who estimated psychosocial demands over five on a scale with eleven boxes, in which "Not at all" and "Greatly" are end points. Red bars represent public and private dentists, orange bars refer to other dental personnel and grey to other professions in Jönköping County during 1994-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of making comparisons with other professions (n =1211, unpublished material, Rolander 2010).](image)

**Health and signs of ill health**

Work-related musculoskeletal disorders (WMSDs) or occupational musculoskeletal disorders are very common in the adult population (Badley et al., 1995, da Costa and Vieira, 2010, Hagberg and Kuorinka, 1995). Neck and upper limb pain among working-age adults
contributes to sick leave. (Walker-Bone and Cooper, 2005). Between 0.5 and 2% of the gross national product in some European countries is connected with work-related disorders (Buckle and Devereux, 2002). According to a statistical report from Sweden in 2008 (Swedish Work Environment Authority, 2008. Work-related disorders., 2008:5), 21% of all employees reported physical symptoms caused by work during the last 12 months and 7% reported sick leave due to these symptoms. The prevalence of physical symptoms went down for women but not for men during the time period 1998-2008. The rate of sick leave due to musculoskeletal disorders was unchanged during the same period for both men and women.

Also for dentists, many studies indicate high prevalence of muscular disorders (Akesson et al., 1999, Newell and Kumar, 2004, Oberg and Oberg, 1993, Rundcrantz et al., 1991, Alexopoulos et al., 2004). The most common areas of complaints are the neck, shoulders and lower back where studies indicate prevalence’s between 63% to 93% (Hayes et al., 2009, Leggat et al., 2007).

In Australia reported 82% of the dentists one or more WMSD, e.g. 39% reported back pain and 25% reported headaches. Female dentists reported a higher proportion of pain than men. Problems are also reported, to a lesser extent, in the wrists, hands and legs. Experience of pain on at least a weekly basis was reported by between 17 and 24% in the neck, shoulders, upper and lower back; and for 14 to 19%, the pain affected activities at home or in leisure time.

Age, gender and perceived general health status are reported to be strongly associated with chronic complaints and seeking medical care. Elderly people, women, and those who experience poor general health, also report more chronic complaints. Back pain has been reported to be more associated with sickness absence than neck and shoulder pain (Yamalik, 2007). Symptoms such as Carpal Tunnel Syndrome (CTS), ulnar nerve entrapment, pronator syndrome, tendonitis, tenosynovitis, thoracic outlet syndrome and rotator cuff tendonitis may occur among all dental personnel (Yamalik, 2007). To sum up, dentists report a high prevalence of various types of work-related musculoskeletal symptoms and most are perceived symptoms from the neck, shoulders and lower back.

The web questionnaire in Jönköping County included questions on musculoskeletal symptoms and their impact on work for the years 1992 to 2008. When compared with other occupational groups in Jönköping County, dentists have a slightly higher prevalence of back pain (Fig. 3,
blue bars). A relatively small proportion in all occupational groups think that the low back disorders affect their work (Fig 3, red bars). For neck and shoulders are the prevalences similar but a lower proportion think that the symptoms affect their work. (Annex 4 and 5).

Figure 3. Percentage of reported prevalence for disorders in lower back but no effect on work (Blue bars). Red bars indicate the percentage of employees in Jönköping County who think that lower back disorders affect work during 1992-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, comparisons with other professions (n = 2816, unpublished material, Rolander 2010).
Work ability and sick leave

Impaired health may increase the risk of sick leave and thus have a negative impact on production (Vahtera et al., 2000, Karlsson et al., 2010). The reasons for sick leave are complex, but sick leave is mainly an indicator of ill health (Alexandersson, 1995) and may be due to individual factors, work-related factors, lifestyle and social factors. Several studies have found associations between organizational change, perceived stressful work conditions, and sick leave (Vahtera et al., 2000, Alexandersson and Norlund, 2004, Kivimaki et al., 1997). Karlsson et al.,(2010) defined psychosocial factors of relevance for production loss measured in terms of sickness absence and presenteeism. They found significant associations between psychosocial work factors, such as work demands, and loss of production; health partly mediated this relationship. The recovery potential at work may also affect sick leave (Hansson et al., 2008). Sick leave, in combination with other factors such as employee job satisfaction, job well-being and disability pensions, is also influenced by how leadership is performed (Kuoppala et al., 2008).

The total amount of sick leave expressed in whole days was for the whole Jönköping County 5.9 percent and for dentists in 2003 about 4.5 percent. In 2008 did sick leave drop to just below 2.8 percent while the mean average in Jönköping County was in 2009 about 3.8 percent (Jönköpings County Council's internal statistics).

Self-perceived work ability is a strong predictor of ongoing and future sick leave (Braathen et al., 2007). Johansson (2007) suggests that the reasoning behind going on sick leave may be affected by how individuals assess their own ability in relation to perceived work demands, and by the balance between incentives and requirements of attendance and absence. Professional groups such as dentists are probably committed to their jobs and attendance requirements may be experienced as high (Berthelsen et al., 2008), which may reduce sick leave absence, and increase sickness presence.

Ergonomic intervention

Most ergonomic interventions at work are oriented towards the individual. However, a change may be underway for ergonomic interventions, from an essentially individual approach, focusing on physical factors, to a more interactive one, with both a physical and a psychosocial angle as a starting point for various operations (Westgaard and Winkel, 2002).
There is weak support for positive effects of individually targeted ergonomic interventions for employees with symptoms from the musculoskeletal system (van Oostrom et al., 2009, Leyshon et al., 2010, Rundcrantz et al., 1991).

Arm support, ergonomics training and workplace adjustments new chairs and rest breaks help employees with musculoskeletal disorders (Kennedy et al., 2009) and, combined with physical exercise, they may reduce symptoms of the neck and upper limbs (Bernaards et al., 2006a). Strenuous physical exercise during leisure time may also reduce the risk of future psychological complaints, poor general health and long-term sickness in a working population (Bernaards et al., 2006b). In a systematic review Franche et al.,(2005b) show that work-style interventions focusing on body posture and workplace adjustment can reduce work disability duration and associated costs.

An important aspect of interventions programmes is to engage stakeholders in the process (Franche et al., 2005a, Tornstrom et al., 2008). Further, it is probably a more successful approach to introduce system thinking, which deals with whole systems, in order to consider how to integrate human factors into complex organizational development processes rather than parts or individuals (Neumann et al., 2009). This is an approach that is rare among ergonomists, who generally prefer to target their efforts individually (Whysall et al., 2004).

Ergonomic interventions for dentists have had an individual focus. The objective of an ergonomic programme is to fit the job to the worker and to minimize the amount of physical and psychosocial stress during work. For example, dentists with clinical ergonomic education and training are less likely to have lower back pain. Furthermore, ergonomic designs that are based on anatomical, physiological and psychological knowledge, on the use of space, the needs of patients and the movements of people, may reduce the risks. Yamalik (2007) suggest that every aspect of practice implies ergonomic considerations and it is necessary that dental ergonomics involves all aspects of practice organization, management, methods of working and organization of treatment.

It has been shown that dentists can recognize and identify their own postures, practice positions and the equipment usage patterns that are associated with increased risks of experiencing musculoskeletal pain and discomfort (Rucker and Sunell, 2002). Prevention or reduction of symptoms in the musculoskeletal system can be successful in terms of more
efficient use of body and dental equipment, and implementation of a daily self-care programme and cognitive-behavioural modifications (Yamalik, 2007).

Organizational ergonomic intervention
In summary, the results of several studies show that today most ergonomic interventions are targeted individually, and not very often at the organizational level. In order to implement effective intervention at the system level, it is necessary to have a knowledge of physical and psychosocial conditions and understand the risk of decreased work ability, increased prevalence of musculoskeletal disorders and sick leave, and their mutual influence. This is important in order to match the right measures with the right field for the best cost. Unfortunately, most research shows that rationalization does not have a primary health focus, and usually has a negative impact on the working environment (Westgaard and Winkel, 2010).

Conceptual model under study
The studies in this thesis are based on a conceptual model which is a modified version of an exposure-effect/response model of the relationships between physical and psychosocial exposure and musculoskeletal health effects suggested by (Westgaard and Winkel, 1996). Based on previous research, it is assumed that organizational and technological conditions to a large extent affect the work environment, the way in which time is used, and levels of physical and psychosocial demands (Marras et al., 2009). It has been suggested that work environment demands are important for muscular load (Westgaard and Winkel, 2002), muscular fatigue (Hummel et al., 2005, Minning et al., 2007) and development of muscular disorders (Badley et al., 1995, da Costa and Vieira, 2010, Hagberg and Kuorinka, 1995), work ability and sick leave (Walker-Bone and Cooper, 2005). The magnitude of individual reactions to the demands from the work environment may depend on work ability, which considers the relation between capacity and the demands on the worker (Ilmarinen, 2009). Decreased work ability arises when the worker’s capacity does not exceed the demands at work with a certain safety margin (Tuomi et al., 1997). The model shows that at all levels there is assumed to be an interaction with production (Christmansson et al., 2002, Landsbergis et al., 1999b, Womack et al., 2009) figure 4.
Organizational and technical changes in dental care in Jönköping County, Sweden

In Jönköping County in Sweden, public dental care faced financial problems at the beginning of the 2000s and there was a need to recruit dentists, as public dentistry could not fulfil the demands of the Swedish welfare system. Rationalizations to cope with the dental crisis were implemented in the public system: dental care was reorganized into smaller units with increased financial control; some work tasks were transferred to other clinics to improve access in terms of longer opening hours; and some units were downsized. The staff were offered competence development and technology was improved (Munvärdet, 2003:3). During the period 2003-2008, the following rationalizations (Figure 5) were implemented:

Organizational changes
- Reorganization into smaller units that bear their own costs and introduction of one more management level. Some clinics were downsized and activities were merged with other clinics.
- Financial feedback per unit each month.
- Delegation of tasks from dentists to other professions.
- As a result of annual salary revision during the period, salaries for dentists increased from below the national average to slightly above.

Technical changes
- SMS reminders to patients to reduce the number of missed appointments.
- Digital X-ray.
- A self-service system, where patients register on a screen when they arrive at the clinic, thus providing immediate information to the dentist that the patient has arrived.
- A new IT system to enable online communication between healthcare providers and insurance funds.

Figure 5. Overview of rationalizations and mailed questionnaires in public dental care in Jönköping County between 2003 and 2008.
**MAIN AIM**

The main aim is to study dentists’ physical and psychosocial work conditions and associations with musculoskeletal disorders, work ability and sick leave during a period of extensive rationalizations; secondly to assess what factors contribute to the risk of illness during rationalizations as a basis for recommendations for preventive measures.

**Specific aims**

Paper I. To identify perceived musculoskeletal disorders and intensity of pain among dentists and to assess the associations with perceived psychosocial and physical work conditions.

Paper II. To evaluate relations between perceived physical work demands and observational data on movements in dental work among dentists who report high physical load.

Paper III. To evaluate if those dentists who report high physical load also show sEMG signs of high muscular activity, muscular fatigue or poor accumulated muscular rest time.

Paper IV. To evaluate whether psychosocial work factors, personality traits and social desirability tendencies affect perceived work posture and precision demands.

Paper V. To analyse changes and associations in perceived work conditions, health measures and production during a period of rationalizations in the dental care organization.
MATERIAL AND METHODS

In Jönköping County, all forty-two dental clinics (with a total of 712 employees) were invited to take part in Paper I. Thirty-two (76%) of the 42 clinics, with a total of 391 employees, accepted the invitation and were informed about a forthcoming mailed questionnaire. Of 338 participants who reported disorders of the musculoskeletal system, 91 persons stated that their work was not the cause of their disorders. Sterilization assistants (6 persons) and dental technicians (2 persons) were excluded because the groups were too small. The remaining 239 participants reported that their work was the cause of their musculoskeletal pain and disorders. They fulfilled the criteria for joining the final study sample, which comprised dentists, dental nurses, dental hygienists, and administrative personnel. External and internal dropouts are presented in Figure 6.

Flow chart of dental personnel included in Paper I

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The mean age of the 239 respondents included in the final study sample, was 45 years (sd = 8.3). The majority (85%) were females, and the mean period of employment was 18 years (sd = 8.8). In total there were 73 dentists in this group: 39 females and 34 males (Table 1).

Table 1. Demographic data and self-reported disorders in the musculoskeletal system.

<table>
<thead>
<tr>
<th>Occupational group</th>
<th>Accepted the invitation</th>
<th>Employees with disorders</th>
<th>Disorders caused by work</th>
<th>Included in study</th>
<th>Age</th>
<th>Years at work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentist, woman</td>
<td>48</td>
<td>45%</td>
<td>39%</td>
<td>39</td>
<td>45</td>
<td>8</td>
</tr>
<tr>
<td>Dentist, man</td>
<td>48</td>
<td>42%</td>
<td>34%</td>
<td>34</td>
<td>47</td>
<td>10</td>
</tr>
<tr>
<td>Dental nurse</td>
<td>238</td>
<td>201%</td>
<td>141%</td>
<td>141</td>
<td>141</td>
<td>8</td>
</tr>
<tr>
<td>Dental hygienist</td>
<td>16</td>
<td>16%</td>
<td>11%</td>
<td>11</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>Adm. personnel</td>
<td>24</td>
<td>22%</td>
<td>14%</td>
<td>14</td>
<td>48</td>
<td>7</td>
</tr>
<tr>
<td>Sterilization ass.</td>
<td>12</td>
<td>9%</td>
<td>75%</td>
<td>Excluded</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Photographer</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dental technicians</td>
<td>4</td>
<td>3%</td>
<td>75%</td>
<td>Excluded</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>391</td>
<td>338%</td>
<td>247%</td>
<td>239</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI95% = 95 percent confidence interval  
¹ = Sterilization assistants  
² = Excluded to small groups
Twenty-seven dentists (10 men and 17 women) were included in Studies II and III. They were selected from the 73 dentists reported in Paper I. Inclusion criteria were a score higher than 9.5 (hard conditions) on precision demands\(^1\) (factor 1) and work posture\(^2\) (factor 2) on a 10-point VAS scale. Mean age was 48 (sd=7.1, range=31-60) years. All were employed in dental clinics in Jönköping County, Sweden. They had worked as dentists for an average of 19 (sd=8.5, range=2-35) years. Fourteen dentists worked full-time, and 13 worked part-time 30-39 hours a week. Nine dentists regularly worked overtime. All but one were right-handed.

In Paper IV a group of 152 invited dentists (24 dentists from Studies II and III and 128 invited dentists) working at dental clinics in Jönköping County, Sweden agreed to participate (Figure 7). After the exclusion of 31 dentists who had failed to fill out the questionnaire and 44 dentists who had fail to fill out the personality questionnaire, a final sample of 77 dentists, 36 of them males and 41 females, remained in the study (Figure 7). The mean age of this sample was 48 years (95% CI 46 to 50 years, range 25 to 64 years), and their mean period of employment was 18 years (95% CI 16 to 21 years, range 0.5 to 39 years). Sixty-six percent of those in the sample worked at least full-time (40 hours/week), and 44% frequently worked overtime. Ninety-nine percent were employed permanently.

In Paper V, all 152 dentists employed by the county council of Jönköping in Sweden were invited to participate in 2003. In all, 31 dentists did not answer the questionnaire. In 2008 all 155 employed dentists were invited to take part, but 41 dentists did not answer the questionnaire. Fifty-six dentists from the 2003 group and 41 dentists from the 2008 group did not respond to either of the questionnaires (Figure 7). In all, 65 dentists responded to both questionnaires in 2003 and 2008. In 2003, 52% were women and the average age was 49 years (sd = 9.5). Mean period of employment was 18 years (sd=11). The average working hours in one week was 38 hours (sd=3) in 2003 and 37 hours (sd=6) in 2008.

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\(^1\) In Paper II-IV physical demands

\(^2\) In Paper I work form, Paper II and IV workload, Paper III physical load
Flow chart of dentists participating in Paper II –V

Excluded I
Did not satisfy inclusion criteria of a score higher than 9.5 on factors “precision demands” and “work posture” on 10-point VAS scales.

Dropout II and V
Did not answer questionnaire. Mainly because of engagement in educational programmes or time constraints or disinterest (2003 and 2008) and technical problems (2003).

Dropout III
Did not answer personality questionnaire. Some indicated that questions were too intimate and intrusive, and others mentioned time constraints.

Dropout IV and VI
Did not answer either questionnaire (2003 and 2008).
Study design

Cross-sectional and prospective design

The design in Paper I-IV is cross-sectional, and the design of Paper V is prospective and longitudinal, with two surveys in 2003 and 2008 respectively. In addition, registry data were gathered over a full year in both 2003 and 2008 (Table 2).

<table>
<thead>
<tr>
<th>Year when data were collected</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
<th>Paper V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Cross-sectional</td>
<td>Cross-sectional</td>
<td>Cross-sectional</td>
<td>Cross-sectional</td>
<td>Prospective</td>
</tr>
<tr>
<td>Dimension of study group</td>
<td>n=239</td>
<td>n=27</td>
<td>n=77</td>
<td>n=65</td>
<td>2003-2008</td>
</tr>
<tr>
<td>Self-report</td>
<td>Survey physical environment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Self-report</td>
<td>Survey psychosocial environment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Self-report</td>
<td>Eysenk Personality Questionnaire</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Self-report</td>
<td>Social Desirability Scale</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Register data (T4)</td>
<td>Productivity</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Self-registration</td>
<td>Time of work tasks and coffee breaks</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Observation/checklists</td>
<td>Portable ergonomic observation (PEO)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Video</td>
<td>Portable ergonomic observation (PEO)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Measurements</td>
<td>Height</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Measurements</td>
<td>Weight</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Measurements</td>
<td>Surface electromyographi (S-EMG)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 2. Overview of study design, methods and group size for Paper I–V.

Measures of exposures

Questionnaires

In Paper I, II, IV, and V, data collection was performed with paper-based or web-based questionnaires comprising items on demographic data, physical load, psychosocial work conditions and leadership. Items on demographic data comprised gender, age, period of employment, place of work, form of employment and profession. There were 9 items for assessment of physical work conditions and 46 items for assessment of psychosocial work conditions. The response scale to variables measuring work conditions in the present study was changed from the original Likert scale (Ekberg et al., 1994) to a 10-cm analogue scale consisting of eleven squares, where low values indicated good work conditions except in the case of social support and work control3 for which high values indicated good work conditions. The end points were labelled “Not at all” and “Greatly”.

Observation method

In Paper II, an observation method PEO (Fransson-Hall et al., 1995) was used to observe neck, arms and lower back in motion and record them in frequency (e.g., how many times the neck bent more than 20 degrees), duration (e.g., total amount of time that the neck was bent over 20 degrees) and sequences (e.g., how long on average, the neck bent more than 20

3 In Paper IV Control over work situation
degrees each time), with the help of a software program built into a computer, a model that is adjusted to the prospective study. The study of dentists recorded how much and how long they bend their neck and back during a normal work period, and how long they are sitting, walking and standing during approximately 50 minutes. Observation or video recording began with the day’s first patient and then continued to the end (Andersson, 1983, Bernad, 1997, Fransson-Hall et al., 1995). Dentists were usually observed or videotaped from the right side and the movements of the head and neck were assessed in relation to an imaginary line between the ear and the eye. Other movements such as sitting and walking around/standing and holding the arm above shoulder height is assessed with no fixed reference points. One of the strengths of this approach is that the equipment can be placed in the existing work environment to observe and record the movements involved in the work, and to calculate duration, sequences and frequencies.

![Figure 8. Picture of the dentist’s workplace with the imaginary line between ear and eye added to observe the head-neck movements greater than 20 degrees.](image)

**Technical measurement**

In Paper III, muscle load exposure of the trapezius descendents was bilaterally registered with an EMG recorder, the MyoGuard system (Biolin Medical, Göteborg, Sweden). This system is a portable unit for on-line collection and analysis of myoelectric signals. A detailed description of the system has been presented by (Sandsjö, 2004b).
Both average rectified value (ARV) and mean power frequency (MPF) were analysed. The sEMG recordings were performed during an ordinary working day during approximately four hours at the dentist’s normal workplace. Normalization was performed by dividing all ARV values by the value obtained from the reference contraction and expressed as a percentage of this value. The frequency content of the signal was studied by calculating the frequency spectrum, with the MPF as an indicator of muscle fatigue (Deluca, 1984). The MPF value was normalized in the same way as ARV, with all values expressed as percentages of the value obtained from the reference contraction. Registration of reference and resting values was carried out before starting the measurement during work. Each subject was seated on an ordinary working chair with the lumbar spine resting against the back support. The subject performed three reference contractions, each lasting for 20 seconds. The reference contraction was performed with both arms held horizontally and in about 10° forward flexion from the frontal plane simultaneously without any weight in the hands. Each reference contraction was followed by a registration with the muscle at rest. Three recordings of 20 seconds resting were performed when each subject was sitting with their arms loosely placed on their lap and the shoulder muscles relaxed. The lowest recorded value plus 10% of the reference ARV value was used as rest threshold value, which is the borderline between background or noise activity and muscle activity (Sandsjö, 2004a). All ARV values below the rest threshold value are
assumed to be muscular rest. Furthermore, accumulated muscular rest was calculated as a percentage of the measure time. During the ongoing work the dentists themselves registered all the different tasks and the time at which they were carried out.

**Self-registration**

During the entire period of measurement of sEMG, dentists noted the time for different work tasks and coffee breaks on a task log. This log was then used to identify changes in the sEMG.

**Measures of outcome**

**Questionnaires**

In Paper I, II, IV, and V data about pain and symptoms from the musculoskeletal system, sick leave due to such symptoms and perceived work ability were collected by means of paper-based or web-based questionnaires. There were nine items to assess pain intensity for nine locations on the body (Ekberg et al., 1994). The assessments were made on a 10-cm analogue scale consisting of eleven squares, where low values indicated no or low pain intensity and high values strong pain intensity. The questionnaire also included 27 questions about the prevalence of disorders (Kuorinka et al., 1987) of the musculoskeletal system, and four questions on work ability taken from the Work Ability Index (Tuomi et al., 1998) and four questions on sickness. Results from surveys in Paper I, II, IV and V of the prevalence of symptoms from the musculoskeletal system, work ability and sick leave are referred to in this thesis by the concepts “work-related musculoskeletal disorders”, “work ability” and “sick leave”.

**Registration of productivity (T4 system)**

In Paper V, productivity was measured as the number of treated patients per dentist per year. Productivity data on number of treated patients and planned treatment time in minutes per patient per year were retrieved from the computerized patient records (T4) and consist of register data. Planned treatment time refers to time assigned per patient in the booking system. Information on SMS reminders have been taken from the Swedish dental staff magazine (Munvädret, 2003:3).
Measures of mediating variables

Eysenk Personality Questionnaire (EPQ)

In Paper IV, EPQ was employed for assessment of neuroticism (24 items) and extraversion (23 items) (Eysenk, 1989). The response format to each of the items is “Yes” or “No”. Score for neuroticism is 0-24 and for extraversion 0-23, with higher scores indicating stronger neuroticism and stronger extraversion, respectively.

Marlowe-Crown SD scale (MCSD)

MCSD was used to measure social desirability tendencies (Crowne and Marlowe, 1964). This scale consists of 33 items. A higher score indicates stronger social desirability tendencies (Minimum =0, maximum =33).

Methodological considerations

Research design

The studies in Papers I to IV are cross-sectional. Cross-sectional design is especially appropriate for describing the status of phenomena or for describing relationships among phenomena at a fixed point in time. Another use is by surveying members of the several classes at one point and then comparing the responses of the classes (Polit and Hungler, 1995). In Paper I, II and IV, estimates of precision demands and workload are described as individual phenomena and comparisons are made between independent groups. A weakness of cross-sectional studies is that the data reflect only the very moment they are collected, which prevents causal conclusions. In Paper V the research design is prospective, which makes it possible to study the dynamics of a variable or phenomenon over time (Polit and Hungler, 1995).

In Paper V, survey data on physical, psychosocial and health conditions are compared with production data from the administrative system (T4). During the study period, data were collected on organizational and technological changes over the same period from the staff newsletter. Statistical tests on the associations can be made on the survey data and production data, but not on qualitative data derived from the Staff newsletter. Thus, the possible associations between the organizational/technological changes and changes in survey data or production data could only be based on logical assumptions.
Selection considerations

In Paper I, all 712 employees in dental clinics in Jönköping County, between 22 Feb 1996 and 26 Feb 1997 were invited to participate. The external dropout was 321 employees. The non-participating clinics were contacted and their dropout was due to factors such as rebuilding and reorganization. None of these clinics was regarded as particularly high or low achievers or as deviating in any other way in the working environment from the clinics that participated in the study.

In Paper II and III, 27 dentists were selected because they had reported WMSD, high perceived workload and work demands in Paper I. This might complicate generalization of the results. However, the dentists investigated in the appended papers did not significantly differ from the remaining dentists included in Paper I regarding perceived work posture precision demands, time of employment and gender distribution. In cross-sectional studies, there is always a possibility of healthy worker selection, i.e., that subjects with WMSD are more liable than healthy ones to change jobs. This healthy selection phenomenon is partly supported by a five-year follow-up study among dentists in Sweden (Akesson et al., 1999). Less experienced dentists with shorter time of employment were however more likely to report WMSD in other studies (Leggat and Smith, 2006, Chowanadisai et al., 2000). A possible explanation is that more experienced dentists have developed working techniques and coping strategies to help deal with WMSD. The average time of employment for the dentists investigated in Paper I was 19 years, indicating an experienced group of dentists. The dropout analysis indicates that it is not likely that the healthy worker effect constitutes a problem for the dentists selected in this thesis.

In Paper IV, 152 dentists were invited to participate. A total of 55 dentists did not respond to the questionnaire due to pregnancy, illness, engagement in an educational programme that hindered their taking part, technical difficulties with the web programme for data collection or because of time constraints or disinterest. A total of 121 dentists participated in the study. A follow-up provided no information to suggest that the dropout would be different from those who participated. Furthermore, 44 dentists did not participate as they did not want to answer the personality questionnaire. Some non-respondents indicated that they thought the questions were too intimate and intrusive, and others referred to time constraints. No significant difference was obtained between the final sample (n=77) and those who failed to fill out the personality questionnaire (n=44) on the basic questionnaire, except that this first group had
been employed for a longer period of time (m=18.1 years and CI95%=15.5 to 20.7 years compared with m=13.3 years and CI95%=9.6 to 16.9 years, p=0.03) (Figure 7).

In Paper V, 152 dentists were invited to participate in 2003 and 31 dentists were excluded, as described earlier in Paper IV. Of the 121 dentists who remained, a further 56 dentists were excluded because they had only answered one survey, resulting in a remaining group of 65 dentists in 2003 (Figure 7).

In Paper V, 152 dentists were invited to participate in 2003 and 155 dentists were invited in 2008. In total, 65 dentists responded to both questionnaires and constitute the final cohort (Figure 7). The total dropout in 2003 was 87 dentists (of 152 invited) in 2003 and 90 dentists (of 155 invited) in 2008 (Figure 7).

Respondents in the study have been followed for five years. They may be a selective group due to a healthy worker effect (Li and Sung, 1999), and they have a higher average age and longer average working hours than dentists as a whole in public dental care in Jönköping.

**Ergonomic measurement methods**

There is nowadays a wide spectrum of methods for evaluating ergonomic conditions. The trend is to combine different methods, for example observation methods and direct measurements. The fact that they are used in occupational health as well as in research has provided a large number of methods with different capacities (Li and Buckle, 1999). Regarding which method is most useful, this depends on the costs, capacity, versatility, generality and exactness required (David, 2005). There are well-established methods in load ergonomics for observation of movements and measurements of electrical muscle activity (sEMG) (Winkel and Mathiassen, 1994) and to directly assess internal exposure dimensions in the body (van der Beek and Frings-Dresen, 1998) or angles and speeds in body movements (Inclinometry). These methods provide data with great exactness, but with low versatility and they are resource consuming. Self-report data generate data with a high versatility and is less resource consuming, but they have lower exactness (Winkel and Mathiassen, 1994). By using several different methods several aspects of the work conditions may be analysed. Self-report data give some insight into the occurrence of tasks, activities and time spent. Observations, goniometers and inclinometry provide information about working postures and movements (van der Beek and Frings-Dresen, 1998).
Self-report data

Self-report data were used in Paper I, II, IV, and V. Questions about the physical environment were answered on scales with eleven positions. The anchor points were labelled “Not at all” and “Greatly”. The last expression may have lead to higher estimates and a smaller dispersion, compared with a more powerful expression such as “worst case”. It is conceivable that the narrow dispersion generated a strong correlation, and that the small differences in the high estimates has no clinical significance (Kirkwood and Jonatan, 2003). The data collected are on an ordinal level and not equidistant, and there is a risk of bias in evaluating the size of changes also due to uneven distribution of changes between 2003 and 2008 (Svensson, 2000). Many authors have reported that data on self-reported questionnaire-based workload is associated with serious problems (Hansson et al., 2001, Karlqvist et al., 1994, Wiktorin et al., 1993). Questions concerning working postures involving parts of the body provide too poor reproducibility and it is recommended that they should be evaluated with more accurate methods (Karlqvist et al., 1994, Wiktorin et al., 1996). A possible risk connected with rating scales in the questionnaire is that the dose-response relationship could be underestimated due to higher reported exposure loads than true levels among subjects with complaints (Balogh et al., 2004).

Studies show that well-structured questionnaires during a year can demonstrate satisfactory reliability and internal consistency in the reporting of various complaints from the neck and upper arm, elbow and hand (Eltayeb et al., 2007). A questionnaire is also a useful tool for obtaining information on health effects of changes in the workplace over time (Landsbergis et al., 2002).

It is suggested that personality factors affect the validity of survey responses. Those who are highly neurotic, with a pervasive dimension of personality marked by negative emotions, self-consciousness and a low degree of mastery or self-efficacy, could be expected to use more maladaptive coping strategies, and accordingly to experience a heavier workload and perceive greater physical demands being placed on them than those who are more emotionally stable (Eysenk, 1989, Suls, 1998). In contrast, those who are highly extrovert, a personality trait involving the tendency to be sociable, active and optimistic, and strongly motivated to perceive work positively, could be expected to use more adaptive strategies to cope with the work environment (Eysenk, 1989). It is suggested that tendencies to seek social desirability
promote responses in a manner aimed at achieving social approval, instead of simply giving true and honest answers to questions (Crowne and Marlowe, 1964).

**Observation method (PEO)**

This method is relatively cheap and equipment. A weakness of this method could be that observers may be tired of carefully observing and recording several different moments in time and may thus make wrong alerts. There is a learning effect due to many observations and recordings. The model provides the basis for observation, and recording may be incomplete and may not classify all operations or they may be classified in the wrong groups. Further, it may be difficult to observe all operations. When the dentist bends his/her back forward it may be difficult to see if anyone is supported by the arm. Another weakness is that we observe in a three-dimensional environment, but this records in a two-dimensional environment (Ericsson et al., 1991). However, no difference could be detected between direct observation and video recording (Keyserling, 1986). The observer may have trouble finding good references to compare their data against the values. When comparisons are made with other observers, there are always differences in duration, sequences and frequencies (Ericsson et al., 1991). In comparing the observation of an experienced ergonomist and assessment with an optoelectronic system called Selspot II for registration of three-dimensional movements, there was a high degree of agreement for clearly defined working positions like sitting, standing and walking. But the correlation was low for neck movements and dynamic operations (Leskinen et al., 1997). On the other hand (Kazmierczak et al., 2006) achieved 87% time history agreement between two independent observers. This suggests that the observations of dental healthcare work activities might have acceptable reliability. There is also consistency in the results with a study in which inclinometry was used (Jonker et al., 2009). Both the PEO study and the inclinometry study suggest consistency between the perceived increased physical load and that the work becomes increasingly static for the neck and shoulders.

**Technical measurement (sEMG)**

**Average rectified value (ARV)**

In Paper III, sEMG was used to assess physical workload in terms of internal exposure. The muscular activity of trapezius descendens on both sides was quantified. The recorded myoelectric activity was normalized towards a sub maximal reference contraction of the arms from a defined postures without any weight in the hands and resulted in 100% Reference
Voluntary Electrical Activation (RVE). The reason for the use of sub maximal reference contraction instead of maximal performance test is that maximal efforts are heavily dependent on the participants’ motivation especially among those afflicted with shoulder problems. The reference postures used correspond to about 15% Maximally Voluntary Contraction (MVC) (Mathiassen et al., 1995). sEMG amplitude (ARV%) can be used to obtain an estimate of the physical exposure during work, and a linear relationship between the sEMG signal and exerted force up to about 30% MVC can be expected (Basmajian and De Luca, 1985). However, the validity of translations of sEMG amplitude from the upper trapezius into exerted muscle force and movement was seriously questioned for tasks involving large or fast arm movements (Mathiassen et al., 1995). On the other hand, fast upper arm movements probably occur infrequently in the case of dentists. sEMG activity levels are also influenced by several confounding factors such perceived negative stress and wide inter-individual variation (Rissen et al., 2000, Nordander et al., 2004).

**Mean power frequency (MPF)**

Mean power frequency analysis is used as an estimator to analyse signs of muscular fatigue. There is an relation between lowered frequency spectrum of the sEMG and muscular fatigue during sustained contractions (Deluca, 1984). It has been shown that a reduction of MPF of more than 8%, compared with the initial reference contraction, may be indicative of muscular fatigue (Oberg et al., 1990). Hummel et al. (2005) found that decreased MPF was detected in the upper trapezius muscle during 6 minutes sustained contraction at 30% MVC level. Minning et al (2007) found that at a force amplitude level below 50-60% MVC a decrease of the MPF is difficult to detect, possibly due to the lesser recruitment of type II muscle fibres at such levels. However, the actual measured ARV values corresponded to about 10-15% MVC. This might explain why we did not find any decrease in the MPF values during the sEMG measurements.

**Muscular rest**

With sEMG it is possible to quantify the time proportions of muscular rest (Sandjo et al., 2000, Hagg and Astrom, 1997). This aspect is most relevant for the risk of myalgia. Due to an orderly recruitment of motor units, low threshold muscle fibres type 1 are vulnerable to muscle contractions of long duration, even at very low amplitudes; this is known as the “Cinderella hypothesis” (Henneman et al., 1965, Hägg, 1991). It is possible that variation in muscular load levels will improve the occurrence of motor units substitution (Thorn et al.,
Motor unit substitution indicates an ability to raise the threshold of recruitment for an exhausted motor unit, a factor that might protect for muscle disorders during low static work (Westgaard and de Luca, 1999). Time proportion of total muscle relaxation (accumulated muscle rest%) used as an indicator of recovery time for the low-threshold motor units. The rest threshold level is defined as the mean ARV value of the best, i.e. the lowest, of the attempted rest, to which 10% of the reference voluntary electrical activation (RVE) of reference contraction was added, resulting in a work/rest threshold of about 1.5-2% MVC. This result is higher than in the studies by (Hagg and Astrom, 1997, Hansson et al., 2001), as they used rest threshold value of about 0.5% MVC, which could imply that low muscular physical load is considered as muscular rest instead of as low static load. This might explain the relative higher amount of accumulated muscular rest.

**Productivity - Register data**

In Paper V, productivity data based on information reported annually were retrieved from the administrative system, T4, for 2003 and 2008. Data of this kind are collected for administrative purposes and may therefore be less precise compared with data collected for scientific purposes. Data may also suffer from confounding factors; employees on sick leave or compensatory leave may be absent due to work conditions, which would also have a negative effect on productivity. This would counteract the results of a rationalization aiming to increase productivity, but it might also mean that work conditions are not reported as demanding, as they would be without leave of absence. A confounding situation when the effect of an exposure is distorted by another exposure factor is not uncommon in epidemiological studies (Rothman, 1986).

**Self-registration**

The dentists are expected to record the timing of different work tasks. It is conceivable that some registrations are missed because of demanding tasks or stressful periods.

**Staff newsletter**

*Munvädret* is Jönköping County Council’s newsletter for public dental care employees. The source of information from this magazine has not always been possible to trace; however, it is unlikely that information about current organizational and technical changes is invalid. Changes other than those reported may also have occurred.
Statistics

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<td>x</td>
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<td>Paired samples t-test</td>
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<td></td>
<td>x</td>
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<tr>
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<td>x</td>
<td>x</td>
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<td>Power analysis</td>
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<td>Repeated measure Anova</td>
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<td>Spearman</td>
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<td></td>
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<td>x</td>
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<td>Structural Equation Modelling (S.E.M)</td>
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<td>x</td>
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</tbody>
</table>

Table 3. Overview of statistical methods and software for Paper I-V. The names of the various statistical tests are taken from SPSS 16.1 and AMOS 17.0

In Paper I, the proportion of employees in each occupational group with work-related musculoskeletal disorders was tested with Chi²-test. Discrepancies in age, years in work, physical/psychosocial work conditions and estimated pain intensity between occupational groups were tested with independent samples t-test, Z-test, Mann-Whitney U-test, One-way ANOVA with post-hoc test and Kruskal-Wallis H. Relationships between pain intensity, physical and psychosocial work conditions for each occupational group were tested with Pearson’s correlation coefficient, Spearman rank correlation coefficient and linear step-wise regression analysis. Significance limit was α=0.05. A power analysis was computed with acceptable level of 80%. In the case of no difference in the results between parametric and non-parametric tests, only those from parametric tests will be presented. All the nine items concerning physical conditions and the 46 items concerning psychosocial work conditions generated five new factors after a reduction with an exploratory factor analysis. The factors are named after the variables included: precision demands (4 items), work posture (3 items), social support (5 items), psychosocial work demands (5 items) and control (4 items)(Paper I).

In Paper II, statistical analysis for differences between groups was performed with independent samples t-test and analysis for relations between data was computed with
Pearson’s correlation coefficient and corrected for mass significance with a significance limit of $\alpha=0.01$.

In Paper III, differences between gender and between dentists in special dental service and district dental service on ARV%, accumulated rest% and MPF% were investigated with covariance analysis, with age and period of employment as covariates. ARV%, accumulated muscular rest% and MPF% during work and coffee breaks were calculated with repeated measure ANOVA, with age and period of employment as covariates. Test of normality was performed using Kolmogorov-Smirnov. Accumulated muscular rest% during work and MPF% during coffee break were significantly separate from normality and were also tested with Mann-Whitney U-test for independent samples and the Wilcoxon signed-ranked test for related samples. Linear regression analysis was performed, with time as an independent sample and ARV%, accumulated muscular rest% and MPF% as dependent variables. Results are presented in correlation coefficients ($r$) for the entire group and in slope coefficients ($B$) on an individual level. Significance limit was $\alpha=0.05$.

In Paper IV, independent samples t-test and Mann-Whitney U-test were used to test differences between gender on physical and psychosocial factors and personality variables. Pearson’s correlation coefficient and Spearman’s rank correlation coefficient were used to analyse relations between factors and variables and multivariate regression analysis were used with the two physical factors as dependent and with the psychosocial factors and personality variables as independent variables. Significance limit was $\alpha=0.05$.

In Paper V, change over time between 2003 and 2008 was calculated with paired samples t-test and relations calculated with Pearson’s correlation coefficient for factors concerning physical and psychosocial work conditions, health and production. An exploratory factor analysis on the 21 outcome items was performed based on 114 dentists who answered a questionnaire in 2008. Principal Component Analysis with direct oblimin rotation extracted three factors labelled “work ability”, “musculoskeletal disorders” and “sick leave”. The explained total variance was 58%. Kaiser-Meyer-Olkin and Bartlett’s Test shows a p-value less than 0.5, which is good. Items measuring musculoskeletal disorders and work ability

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4 Kaiser-Meyer-Olkin’s measure for sample adequacy was used to test partial correlations. Bartlett’s Test of Sphericity was used to test if the correlation matrix is an identity matrix. The p-value was less than 0.5, which means that the correlation matrix is valid.
were standardized due to different response scales. The degree of validity, reliability, and general applicability of the questionnaire was assessed by a confirmative factor analysis on all work condition items, leadership items, sickness measures and productivity data (number of treated adults and children). The analysis was performed on a group of 170 dentists who answered the questionnaire either in 2003 (n=56) or in 2008 (n=49), and the responses in 2008 (n=65), from the dentists who are included in the cohort. The factor model fit evaluated by means of Root Mean Square Error of Approximation (RMSEA) was 0.04. The Comparative Fit Index (CFI) was 0.91 (> 0.90 equals good fit), the root mean square residual, (RMR) = 0.07. An RMR of zero indicates a perfect fit. All values indicate that the fit of the factor model is good. The results confirmed the eleven suggested factors: “precision demands”, “work posture”, “social support”, “psychosocial demands”, “work control”, “work ability”, “musculoskeletal disorders”, “sick leave”, “leadership”, “productivity” and “planned treatment time”. Accordingly, the factor structure is independent of sample and can be generalized at least to public dentists in Sweden.

Relations between variables were evaluated with Pearson’s correlation coefficient. Change over time between 2003 and 2008 was evaluated with paired t-test for related samples. Factor-reliability was tested with Cronbach’s Alpha. Structural Equation Modeling (SEM) was used to assess associations between the variables in the conceptual model (Fig 4). SEM analysis provides opportunities to measure latent variables among multiple manifest variables and to statistically compare alternative conceptual models. While most other multivariate procedures are descriptive, SEM takes a confirmatory approach to data analysis. Traditional multivariate procedures are incapable of either assessing or correcting for measurement error. SEM analysis is also suitable to evaluate the reciprocal direct and indirect relationship between the factors. In Paper V, a methodological concern is the issue of the relatively small groups used in the SEM analysis (n=65) and the complexity of the model. Lower values of the fit indices in the SEM model were to be expected. One reason for the high values found is the clear and simple factor structure (i.e. generally high factor loadings). The reliable and valid factor structures found in Paper I based on a large number of subjects, formed a firm basis for the

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5 A value of about 0.05 or less would indicate a close fit of the model in relation to the degrees of freedom.
6 CFI presents the proportion of variance explained by the proposed model (in this case the factor model explains 91% of the input data).
7 RMR presents the square root of the average squared amount by which the sample variances and covariance’s differ from their estimates obtained under the assumption that your model is correct.
structural analyses performed. Another general reason is that the proposed model fits the empirical data to a high degree.

All statistical analyses and the explorative factor analyses were performed in SPSS, version 16 (SPSS Inc., Chicago, Ill., USA). The confirmative factor analyses and Structural Equation Modelling (SEM) analyses were carried out in the program Analyses of Moment Structures, AMOS 17.0 (SPSS Inc., Chicago, Ill., USA), and LISREL 8.30 (Jöreskog and Sörbom, 1993), and the results are presented in standardized factor loadings and standardized regression weights. Significance limit was $\alpha=0.05$. 
RESULTS

In Paper I, the respondents as a whole reported very high scores on items concerning precision demands. They reported fairly high scores on psychosocial work demands but low scores on work control. For social support, acceptable conditions were reported. Clear differences were found between dentists, dental hygienists and the other professional groups on reported precision demands and work posture. In particular, dentists and dental hygienists reported that work conditions were precision-demanding with poor work posture, but also that they had higher work control (Table 4).

Table 4. Self-reported psychosocial and physical work conditions on an 11-step scale.

<table>
<thead>
<tr>
<th>Occupation group</th>
<th>Social support</th>
<th>Psychosocial work demands</th>
<th>Work control</th>
<th>Precision demands</th>
<th>Work posture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n m CI95%</td>
<td>m CI95%</td>
<td>m CI95%</td>
<td>m CI95%</td>
<td>m CI95%</td>
</tr>
<tr>
<td>Dentist, woman</td>
<td>39 7.5 6.9-8.1</td>
<td>6.9 6.3-7.5</td>
<td>5.9 5.2-6.6</td>
<td>9.6 8.4-9.9</td>
<td>9.0 8.5-9.4</td>
</tr>
<tr>
<td>Dentist, man</td>
<td>34 7.6 7.1-8.0</td>
<td>7.2 6.8-7.7</td>
<td>5.7 5.2-6.3</td>
<td>9.7 9.5-9.8</td>
<td>9.0 8.6-9.4</td>
</tr>
<tr>
<td>Dental nurse</td>
<td>141 7.9 7.6-8.1</td>
<td>6.1 5.8-6.3</td>
<td>4.1 3.8-4.4</td>
<td>8.6 8.3-8.8</td>
<td>8.0 7.7-8.3</td>
</tr>
<tr>
<td>Dental hygienist</td>
<td>11 6.7 6.0-7.3</td>
<td>6.9 5.8-7.9</td>
<td>5.5 4.5-6.5</td>
<td>9.6 9.3-9.9</td>
<td>9.1 7.8-10</td>
</tr>
<tr>
<td>Adm. personnel</td>
<td>14 6.3 5.0-7.6</td>
<td>5.9 4.5-7.4</td>
<td>4.0 2.8-4.9</td>
<td>8.1 7.1-9.1</td>
<td>7.0 5.6-7.8</td>
</tr>
<tr>
<td>Total</td>
<td>239</td>
<td></td>
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<td></td>
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</tbody>
</table>

CI95%= 95 percent confidence interval.

Presence of symptoms was most common in the neck, shoulders and lower back for all occupational groups. Pain intensity, especially in the neck and shoulders, was perceived as lower among dentists than among other professions (Table 5).

Table 5. Location and intensity of self-reported musculoskeletal pain on an 11-square scale.

<table>
<thead>
<tr>
<th>Occupation group</th>
<th>Neck</th>
<th>Shoulders</th>
<th>Lower back</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n m CI95%</td>
<td>m CI95%</td>
<td>m CI95%</td>
</tr>
<tr>
<td>Dentist, woman</td>
<td>39 3.1 2.2-4.1</td>
<td>3.6 2.6-4.6</td>
<td>3.0 2.0-4.0</td>
</tr>
<tr>
<td>Dentist, man</td>
<td>34 3.2 2.1-4.2</td>
<td>3.1 2.1-4.1</td>
<td>4.1 2.9-5.3</td>
</tr>
<tr>
<td>Dental nurse</td>
<td>141 4.5 3.9-5.0</td>
<td>4.9 4.3-5.5</td>
<td>4.0 3.4-4.6</td>
</tr>
<tr>
<td>Dental hygienist</td>
<td>11 5.1 2.2-8.0</td>
<td>5.5 2.5-8.5</td>
<td>4.2 2.0-6.3</td>
</tr>
<tr>
<td>Adm. personnel</td>
<td>14 6.1 4.1-8.1</td>
<td>6.4 4.2-8.5</td>
<td>3.1 1.4-4.8</td>
</tr>
<tr>
<td>Total</td>
<td>239</td>
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<td></td>
</tr>
</tbody>
</table>

CI95%= 95 percent confidence interval.

There was no significant correlation between precision demands, work posture and pain intensity, except for female dentists, who reported significant correlation between the demands for precision and pain intensity in their shoulders (r=0.38, p<0.05) and also between neck pain and social support (r=-0.41, p<0.01) (i.e., perceived pain from the neck was higher when social support was low). Dental hygienists displayed the highest correlations between precision demands and pain intensity in the neck (r=0.73, p<0.05) and shoulders (r=0.67, p<0.05), and also between psychosocial work demands and pain intensity in the lower back.
(r=0.64, p<0.05). These results were supported in a step-wise regression analysis. For other occupational groups correlations were lower.

In Paper II, the 27 dentists reported that work was very precision-demanding (m=9.5) with bad work postures (m=9.0). The PEO analysis of body posture also showed that dentists sit on average 76%, with their head bent forward more than 20 degrees on average 58%, of the observation time. This estimate suggests that dentists have a sitting posture on average 22 hours per week, with their head bent forward over 20 degrees for an average of 17 hours in one week. During the same time they have an average frequency of 2053 forward bends of the head during a week. A reduced frequency of head bending over 20 degrees (r=-0.6, p=0.001) and increased sequences\(^8\) (r=0.5, p=0.006) correlates with a perceived increase in uncomfortable working positions. Thus the results show that when the head position is less dynamic, dentists report a more uncomfortable posture. In addition, there is a clear correlation between body length and perceived pain in the lower back (r = 0.6, p <0.01); the taller the dentist is, the stronger the perceived pain in the lower back will be.

In Paper III, the sEMG recordings showed 31-34% accumulated muscular rest; muscular activity levels were 50-65% of the calibration value, and the normalized MPF values were centred on an initial value of 93-95% during the recorded working time. Regression analysis between ARV% and time during work showed significant correlation coefficients (r), 0.53 (p<0.001) and -0.15 (p<0.05) for the right and left sides respectively. When regression analysis was performed for each individual separately, there was a fairly large variation, with slope coefficients (B) from 70.2 to +0.9 on the right side and from70.1 to+0.4 on the left. Eighteen of the dentists (67%) had negative slope coefficients (B) on the right side and 12 (48%) on the left. The total muscular rest period for dentists (left side 31%, right side 34%) was slightly longer than for a risk group of female cashiers (left side 26%, right side 24%) (Rissen et al., 2000) and female supermarket employees with pain (left side 23%, right side 24%) (Sandsjo et al., 2000). The total result can be interpreted as a sign of prolonged low muscle load during work with uncertain evidence of muscle fatigue. However, there are similarities with risk professions such as supermarket cashiers in the total time for rest and recovery.

\(^8\) The average time for each frequency
In Paper IV, dentists also reported that work was very precision-demanding (m=9.6) with bad work postures (m=8.6) and rather high psychosocial demands (m=6.9). There were clear associations between precision demands and work posture (r=0.5 p<0.01); between precision demands and psychosocial demands (r=0.4 p<0.01); and between work posture and psychosocial demands (r=0.4 p<0.01). A similar result is obtained from multiple regression analysis with precision demands as a dependent variable. The only variable which was added was psychosocial demands with Standardized Beta coefficients (SBc)=0.5 p<0.001) showing associations. In one additional regression analysis with work posture as a dependent variable two variables were added: psychosocial demands (SBc=0.4 p<0.001) and work control (SBc=-0.22 p<0.05). The interpretation may be that when work posture is perceived as worse, psychosocial work conditions are also perceived as worse.

There were no significant correlations between precision demands and personality variables or social desirability variables. These results are interpreted as giving greater credibility to their ratings of physical and psychosocial work environment.

Paper V describes the rationalization and technological changes which have been introduced in dentistry in Jönköping County Council during the period 2003-2008, and analyses the changes and the associations between physical, psychosocial, health and production factors. A significant improvement occurred in perceived precision demands and work posture between 2003 and 2008, while work control and leadership deteriorated significantly during the Paper period. Production measured as number of treatments performed on adult patients increased significantly (Table 6).
Table 6. Factors and variables in mean (m), 95 percent confidence interval (CI95%), probability (p) and correlation (r) with
degree of probability(∗) for 65 dentists. Increasing scores in Precision demands, Work posture, Psychosocial
demands indicates worse conditions. Increasing scores in Social support, Work control, Work ability and
Leadership indicates better conditions.

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2008</th>
<th>p</th>
<th>r</th>
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<tr>
<td></td>
<td>m</td>
<td>CI95%</td>
<td>m</td>
<td>CI95%</td>
</tr>
<tr>
<td>Precision demands</td>
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<td>9,54-9,80</td>
<td>8,91</td>
<td>8,73-9,10</td>
</tr>
<tr>
<td>Work posture</td>
<td>8,56</td>
<td>8,33-8,79</td>
<td>8,15</td>
<td>7,91-8,39</td>
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<td>7,80-8,34</td>
<td>7,86</td>
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<td>Psychosocial demands</td>
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<td>7,00-7,72</td>
<td>6,96</td>
<td>6,63-7,30</td>
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<tr>
<td>Work control</td>
<td>6,54</td>
<td>6,12-6,96</td>
<td>5,89</td>
<td>5,46-6,33</td>
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<tr>
<td>Leadership</td>
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<td>6,26-6,94</td>
<td>6,18</td>
<td>5,87-6,48</td>
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<tr>
<td>Work ability</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M.S. Disorders</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Sick leave</td>
<td>1,13</td>
<td>1,04-1,24</td>
<td>1,16</td>
<td>1,05-1,27</td>
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<td>Productivity, Number of adults treated during one year per dentist</td>
<td>547</td>
<td>467-627</td>
<td>665</td>
<td>576-754</td>
</tr>
<tr>
<td>Productivity, Number of children treated during one year per dentist</td>
<td>446</td>
<td>389-503</td>
<td>477</td>
<td>411-543</td>
</tr>
<tr>
<td>Productivity, Planned treatment time, minutes, adults treated during one year</td>
<td>34</td>
<td>32-37</td>
<td>33</td>
<td>31-35</td>
</tr>
<tr>
<td>Productivity, Planned treatment time, minutes, children treated during one year</td>
<td>25</td>
<td>22-27</td>
<td>23</td>
<td>21-26</td>
</tr>
</tbody>
</table>

Degree of probability for Pearson’s correlation coefficient (r) *=p<0.05, **=p<0.01, ***p<=0.001. Standardized= (Very good, -0.84 to 2.98, Very poor in 2003) and (Very good, -0.80 to 2.49, Very poor 2008). Standardized= (No disorders, -1.04 to 1.37, Great inconvenience 2003) and (No disorders, -1.25 to 1.48, Great inconvenience 2008).

In the SEM analyses between factors that reflect the physical and psychosocial work
environment, health and production, the starting point was the hypothetical model. (Figure
10).

The best fitting model in the SEM analysis only included physical work conditions as
predictors of the health- and work ability measures, while psychosocial work conditions were
excluded. The model indicates that health is affected by work conditions, and also that health
is a mediator between work conditions and productivity. There is a difference between 2003
and 2008, as planned production time enters into the suggested causal chain after
rationalizations, indicating that scheduled work planning has become a more direct instrument
for productivity (Figure 10).

Figure 10. SEM testing associations between latent variables on two occasions (2003 and 2008) respectively,
and associations between the two occasions. Standardized regression weights (SRW) of direct effects are
presented. RMSEA=0.00 CFI=0.92, and RMR=0.09. All effects are significant (p<0.05). The factor loadings of
the 32 manifest variables or measures are excluded from the figure.
In a second expanded structural equation analysis, work control and psychosocial demands were included. The fit of this model was lower compared with the basic model presented (RMSEA=0.00, CFI=0.75, and RMR=0.11). However, some interesting effects were found. Work control in 2003 had a direct path to work ability in 2003 (-0.40) and to work control in 2008 (0.44). Psychosocial demands were associated with precision demands in 2003 (0.60) and with work ability in 2008 (-0.40). Social support and musculoskeletal disorders did not fit into the best fitting model (Annex 6, expanded model).
DISCUSSION

The results in the thesis show a consistent picture of high perceived physical load due to high precision demands and uncomfortable work postures among dentists. As recommended by other researchers (van der Beek and Frings-Dresen, 1998), self-rating of work conditions in questionnaires (Paper I and IV) was further elucidated by other ergonomic measurement methods in Paper II and III. The PEO analysis in Paper II showed that dentists sit with their head bent over 20 degrees for long periods, and that in particular a less dynamic head position is associated with self-perceived physical load. The results give an estimate of an average of the head bent more than 20 degrees for about 17 hours a week (Paper II) during psychosocially demanding circumstances (Paper IV). In Paper III, sEMG measures indicate that dentists have signs of prolonged low muscle load during work. A study by Jonker et al. (2009) used inclinometry to measure physical load. The results of that study support the notion that a deterioration in working position occurs when work becomes less dynamic (Jonker et al., 2009). In comparison with other risk groups such as cashiers (Rissen et al., 2000) and supermarket employees (Sandsjö et al., 2000), the results for the dentists indicate an even worse work situation. Self-rated assessments of precision demands and work posture correlated in the questionnaire data, indicating that the precision-demanding dental work in patients’ mouths also demands uncomfortable working postures.

Dentists reported high psychosocial demands but good work control (Paper I and IV). In a number of epidemiological studies, psychosocial demands have been shown in several studies to be a risk factor for stress (Karasek and Theorell, 1990, Lavoie-Tremblay et al., 2008, Roquelaure et al., 2009) as well as for musculoskeletal disorders (Ahlberg-Hulten et al., 1995, Bejerot, 1998, da Costa and Vieira, 2010, Hansson et al., 2001, Walker-Bone and Cooper, 2005, Wilson et al., 1998, Aronsson et al., 1992, Feyer et al., 1992, Hagberg and Kuorinka, 1995). Studies have also shown that psychosocial work conditions may interact with physical work conditions in their effects on health and well-being (Walker-Bone and Cooper, 2005). This is reasonable, as in practice the work situation cannot be separated into different independent parts, but is rather a complex of a number of mutually interacting conditions. Good psychosocial work conditions may however act as a buffer against effects of physically demanding work conditions, while strenuous psychosocial work conditions may exaggerate the perceived physical load (Karasek, R 1990, Wainright and Calnan, 2002).
Individual responsiveness and reactions to the work situation also depend on individual characteristics. In Paper IV, dentists’ response dispositions, in terms of neuroticism and tendency to respond in a socially desirable way, were investigated. The results did not lend any support to an assumption of bias in their way of responding. Rather, the results further support that their perception of high physical workload and limitations in the psychosocial work conditions are valid.

The rationalizations implemented in dental care in Jönköping County during the 2000s are based on NPM and have contributed to more business-like dentistry (Almqvist, 2006a, Bejerot, 1998). They comprised both organizational and technical changes which may have affected dentists’ work conditions in different ways. The aim of rationalizations is to improve productivity and reduce costs. Studies of effects on production most commonly use self-perceived production (van den Heuvel et al., 2010, van den Heuvel et al., 2007) or sick leave and presenteeism (Karlsson et al., 2010) as indicators of production. Several studies (van den Heuvel et al., 2007, Stewart et al., 2003) have shown that among employees with common pain conditions or upper extremity disorders, sick leave has less effect on productivity losses than presenteeism. Among the study group of dentists it is assumed that there is high professional commitment (Berthelsen et al., 2008), which according to (Johansson, 2007) may contribute to presenteeism, rather than absence due to sick leave. Sick leave among dentists in Jönköping County was comparably low, while effects of sickness presence are not captured in the studies.

A strength of Paper V is the inclusion of real production measures, such as number of patients treated per year as well as planned treatment time per patient. The latter measure probably in particular reflects the organizational steering of production. In Paper V, production was shown to increase during the period of rationalizations. The SEM analysis shows that there are both direct and indirect associations between work conditions, health/illness and productivity.

Health/illness act as intermediary variables between work conditions and production, as was also assumed in the conceptual model (Figure 4). Karlson et al.,(2010) found similar results, i.e. that health is an intermediary between work conditions and production, although the outcome in her study is not actual production.
Based on previous research it was expected that work conditions would change for the worse during rationalizations (Landsbergis et al., 1999a, Westgaard and Winkel, 2010). However, the results rather showed improvements in perceived precision demands and work postures, and a tendency for improved psychosocial demands, but still at a very poor level. The fact that the dentists felt that their work was less physically demanding is supported in a study by (Jonker et al. In Manuscript), showing that there is a tendency to increased porosity, i.e. more time for recovery, during work.

The association between precision demands and work posture suggests that dentists’ work postures are influenced by the precision-demanding tasks dentists perform in the limited surface of the patient’s mouth. Associations between precision demands and work posture are well documented in other studies (Finsen et al., 1998, Valachi and Valachi, 2003). Perceived precision demands and work posture improved over the five-year study period. This improvement in physical work conditions does not seem to lead to less sick leave or improved work ability despite the direct association in the SEM analysis. One explanation could be that physical load is still at a high level and that the improvement was not large enough. In addition, a five-year period could be too short to have an effect on health/illness.

The new organization is designed to facilitate communication between managers and employees, improve leadership and increase motivation and engagement (Munvädret, 2003:3, Munvädret, 2009:3). One feature of the rationalizations that were implemented is the delegation of some tasks from dentists to other professions, which may also involve increased demands on team work. This may be a two-edged sword, as dentists’ work tasks may become less varied, both physically and mentally, while the change may also involve more interaction and collaboration with other professions. Since the dentist still has the medical responsibility, delegation of tasks may be perceived as a loss of control over the quality of work. From the employer’s perspective there is an economic incentive for delegation of tasks, as other professions are cheaper. The rationalizations also meant that each dental unit was to bear its own costs, combined with increased economic feedback, which may have contributed to the decrease in perceived work control and reduced appreciation of dental leadership during the study period.

The introduction of SMS reminders reduced the number of missed appointments among adults (Munvädret, 2009:3). A consequence of this may be that production of the dental work
better follows planned production. In the SEM analyses, production time entered into the model in the follow-up, probably due to a better fit between organizational planning of production and actual production. It may be expected that this would lead to a perceived increase in control over the work situation, but the results of Paper V rather show decreased control at the follow-up. Work control is a complex concept and rather reflect dentists’ attitudes to demands on delegation of tasks, economic control, and one more level of management in the organization. The implication of rationalizations is that dentists take all decisions concerning the medical treatment of the patient, while the type of work is not affected by organizational changes. When it comes to decisions that are comprehensive in nature, such as the digitization of medical records or delegation of tasks to other professions, decisions are made in the management team while the dentist still has the main medical responsibility (SOU, 2002).

Several studies have shown that musculoskeletal disorders are a problem for dentists (Hayes et al., 2009, Leggat et al., 2007). Interestingly, in the SEM model musculoskeletal disorders are not associated to the other factors in the analysis.

In Jönköping County the prevalence of musculoskeletal symptoms ranges between 60 and 70% for the neck and shoulders, while only about 5-10% think it affects their work (Annex 4 and 5). For the lower back the figures are roughly the same (Figure 3). The results in Paper V suggest that prevalence of symptoms is a poor indicator of physical load.

In order to reduce the risk of increasing load it therefore seems important that production-oriented engineers work with ergonomists to find viable systems (Wells et al., 2007). Knowledge of the effects of rationalizations on safety, productivity, biomechanical and psychosocial exposure and health/illness in public organizations is still very limited, and knowledge of how the work environment is best implemented needs to be developed.

It is well established in a number of studies that previous sick leave is a strong determinant of later sick leave, as is also confirmed in Paper V. The reasons for sick leave are complex (Alexandersson, 1998) and a number of work-related and other factors have been shown to predict future sick leave (Kuoppala et al., 2008). The best-fitting SEM model did not include psychosocial work conditions as determinants of the health/illness outcomes in this study.
These results may indicate that the psychosocial factors are not as important as physical conditions for health/illness and production among dentists. There may however be an interaction between physical and psychosocial work conditions, as the results in Paper IV show worse ratings of demanding work posture among those who had higher estimates of psychosocial demands and less control over their work situation.

Actual production is the key issue for management and is therefore an interesting measure for interventions and preventive work, if production is associated with work conditions and health as suggested by the results in Paper V. Preventive interventions by e.g. occupational healthcare it may be necessary to utilize presenteeism as a more useful measure of the outcome of risk environments than sickness absence. Given the effects on production, this outcome measure would more likely improve employers’ interest in preventive interventions.

In summary the results in the thesis show a consistent picture of high perceived physical load due to high precision demands and uncomfortable work postures during psychosocially demanding circumstances. Dentists sit with their heads bent forward during approximately 40% of their working time with signs of prolonged low muscle load in the shoulders. The implemented rationalizations in Jönköping County during the period 2003-2008 has not led to deterioration in the physical environment in spite of the fact that the dentists produce more treatments of adult patients than before. This result may indicate that rationalizations do not always lead to increased health risks; it depends how they are implemented. Dentists may have changed the way they work for the better, and due to task delegation and SMS reminders a smoother patient flow may have been achieved, resulting in a reduction of workload and perceived stress regarding financial loss. This may be the expression of smarter working for dentists or a smarter dental organization. It seems appropriate that measures to improve the working environment in dentistry should be preventive, focusing on an organizational level primarily on improving the physical environment and its associations with psychosocial work conditions and health.
CONCLUSION

- Still high physical workload, despite an improvement which is supported by results from both PEO (Paper II) and sEMG (Paper III) methods.

- Perceived musculoskeletal disorders have little impact on work ability and sick-leave.

- There is an association between perceived physical conditions and psychosocial demands.

- During the period of rationalizations will the majority of the association chains in the SEM. analysis between the factors not change for 2003 and 2008 which indicates stable associations.

- The SEM analysis could not reproduce the hypothetical model because the psychosocial factors and musculoskeletal do not fit.

- Despite increase in production is not dentists working harder, depending on the delegating of tasks to other professionals and smoother patient flow which may have resulted in a smarter way of working from an organizational perspective.
ISSUES FOR FUTURE WORK

Despite great efforts in occupational health in Sweden over time, as well as clear health and safety legislation, there are still physical and psychosocial problems that are work-related.

It is important to gain greater insight into how rationalization can also provide indications of consequences in the workplace, and investigate how specialists in occupational health can influence the organizational changes implemented and consequently, assess increased risk of illness among staff and influence the direction of organizational change.

Another important issue is that occupational health today is made up of specialists who investigate and resolve each profession’s specific area. But problems at work are often complex and originate from both physical and psychosocial conditions. Work environment problems are often considered from the perspective of the field which the professional occupational health consultant belongs to and not as an entity. To prevent sickness and reduced productivity among dentists, the complex interaction between organizational, technical, and work environment conditions suggests that occupational health services should incorporate a stronger multidisciplinary perspective than today; this also includes organizational perspectives. Even if cooperation occurs between different specialists in occupational health, it is important to explore whether the cooperation needs to be improved and if so how it can be implemented.
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REFERENCES


Annex 1. Percentage of estimated precision demands over five on a scale with eleven boxes, in which "Not at all" and "Greatly" are end points. Red bars represent public and private dentists, orange bars refer to other dental employees and yellow bars represent other professions in Jönköping County during 1992-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of making comparisons with other professions (n = 2816, unpublished material, Rolander 2010).
Annex 2. Percentage of estimated social support at work over five on a scale with eleven boxes, in which “Not at all” and “Greatly” are end points. Red bars represent public and private dentists, orange bars refer to other dental personnel and grey to other professions in Jönköping County during 1994-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis (n = 1211, unpublished material, Rolander 2010).
Annex 3. Percentage of estimated work control over five on a scale with eleven boxes, in which "Not at all" and "Greatly" are end points. Red bars represent public and private dentists, orange bars refer to other dental personnel and grey to other professions in Jönköping County during 1994-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of making comparisons with other professions ($n=1211$, unpublished material, Rolander 2010).
Annex 4. Percentage of reported prevalence for disorders in the neck but no effect on work (Blue bars). Red bars represent the percentage who think that neck disorders affect work in Jönköping County during 1992-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of making comparisons with other professions (n = 2816, unpublished material, Rolander 2010).
Annex 5. Percentage of reported prevalence for disorders in the shoulders but no effect on work (Blue bars). Red bars represent the percentage who think that shoulder disorders affect work in Jönköping County during 1992-2008. Test group includes the same dentists who participated 1996, 1997, 2001 and 2004. Data were collected with the same questionnaire and methods used in the various papers in the thesis, for the purpose of making comparisons with other professions (n = 2816, unpublished material, Rolander 2010).
Annex 6. Expanded model of SEM testing associations between latent variables on two occasions (2003 and 2008) respectively, and associations between the two occasions. Standardized regression weights (SRW) of direct effects are presented. RMSEA=0.00 CFI=0.75, and RMR=0.11. All effects are significant (p<0.05). The factor loadings of the 32 manifest variables or measures are excluded from the figure.

Annex 7. SEM testing indirect associations between latent variables on two occasions (2003 and 2008) respectively, and associations between the two occasions. Standardized regression weights (SRW) of indirect effects are presented. RMSEA=0.00 CFI=0.92, and RMR=0.09. All effects are significant (p<0.05). The factor loadings of the 32 manifest variables or measures are excluded from the figure.