Musculoskeletal disorders and psychosocial factors at work
Effects of a participatory ergonomics intervention in a
cluster randomized controlled trial

Eija Haukka

ACADEMIC DISSERTATION

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ABSTRACT

The primary aim of this study was to examine the efficacy of a participatory ergonomics (PE) intervention in preventing musculoskeletal disorders (MSDs). Secondly, the effects of the intervention on psychosocial factors at work as intermediate outcomes were examined. Thirdly, the occurrence of multiple-site musculoskeletal pain (MSP), as well as its associations with psychosocial factors at work and mental stress, was studied.

A cluster randomized controlled trial of 504 workers of 119 municipal kitchens in four large cities in Finland was conducted during the years 2002-2005. The kitchens were randomized to an intervention (n = 59) and control (n = 60) group. The intervention lasted 11 to 14 months. In eight 3-5 hour workshops, the workers were guided to identify strenuous work tasks and to seek solutions for decreasing physical and mental workload, as assisted by a researcher trained in ergonomics. The main outcome measures were the occurrence of and trouble caused by musculoskeletal pain in seven anatomical sites (neck, shoulders, forearms/hands, low back, hips, knees, and ankles/feet), localized musculoskeletal fatigue after the working day, and sick leaves due to musculoskeletal complaints. The following psychosocial factors were studied as intermediate outcomes: mental stress, mental strenuousness of work, hurry, job satisfaction, job control, skill discretion, co-worker relationships, and supervisor support. Data were collected by questionnaire at baseline and thereafter every three months during the intervention and the 12-month post-intervention follow-up. A total of 402 changes related to ergonomics were implemented. In the control group, 80 such changes were spontaneously implemented as a part of normal activity. The intervention did not reduce perceived physical workload and no systematic differences in any health outcomes were found between the intervention and control groups during the intervention or during the 12-month post-intervention follow-up. The effects on the psychosocial factors at work were adverse. At the end of the intervention, the workers in the intervention group reported more job dissatisfaction, greater mental stress and poor co-worker relationships compared to the control group. The adverse overall effects were mainly due to a joint effect of the intervention and unconnected organizational reforms taking place in the foodservice in two of the participating cities. The results suggest that intervention as implemented in the present
trial is not useful in reducing perceived physical workload, improving unsatisfactory psychosocial working conditions or preventing MSDs. If organizational reforms are expected to occur, the introduction of other concomitant workplace interventions should be avoided. There is a need for further high quality trials to elucidate the effectiveness of PE interventions.

The co-occurrence of pain in seven anatomical sites was studied in a cross-sectional study (n= 495 women) at baseline, before the intervention started. About 73% of the women were experiencing pain in at least two, 36% in four or more, and 10% in six to seven sites. Thus, MSP was more common than single-site pain (14%) or no pain at all (13%). The seven pain symptoms occurred in 83 different combinations, in addition to those with no pain and with pain in one site only. When the co-occurrence of pain was studied in three larger anatomical areas (neck and low back, upper limbs, lower limbs), concurrent pain in all three areas was the most common combination (36%). Concurrent pain in all three areas increased successively with age from 22% in the youngest group (≤ 40 years) up to 49% in the oldest group (≥51 years).

Associations of psychosocial factors at work and mental stress with MSP were studied in a two-year longitudinal study (n= 385 women). Questionnaire data which were collected at three-month intervals in the intervention study were used. Since no effects of the intervention were found on MSDs, the occurrence of MSP, or perceived physical workload, the randomized design was relaxed. The 3-month prevalence of MSP (defined as pain at ≥ 3 of seven sites) varied between 50% and 61% during the two-year follow-up. In time-lagged generalized estimating equations, psychosocial factors at work predicted MSP being reported three months later, and vice versa, MSP predicted adverse psychosocial factors at work. Developmental patterns of MSP and psychosocial factors were identified by trajectory analysis. Four trajectories of MSP prevalence emerged: Low, Descending, Ascending, and High. A two trajectory model- Ascending or High vs. Low - yielded the best fit for the psychosocial factors. Poor co-worker relationships, mental stress and hurry at baseline predicted belonging to the High MSP trajectory. MSP at baseline predicted belonging to the trajectories of Ascending low job control and mental stress. Adverse changes in most psychosocial factors were associated with belonging to the High and Ascending MSP trajectories. The reciprocality of these relationships implies
either the existence of two mutually dependent processes, or some shared common underlying factor(s).

In the daily work of occupational and healthcare professionals, in epidemiological research, and in connection with further interventions, the evaluation and prevention of pain at multiple anatomical sites might be useful in addition to considering single-site pain. Since MSP and psychosocial factors at work seem to be strongly linked together, the assessment of both parameters in parallel is recommended.
LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original articles referred to in the text by their Roman numerals:


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# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BL</td>
<td>Baseline</td>
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<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>CI</td>
<td>Confidence interval</td>
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<tr>
<td>CRT</td>
<td>Cluster randomized controlled trial</td>
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<tr>
<td>CTS</td>
<td>Carpal tunnel syndrome</td>
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<tr>
<td>CWP</td>
<td>Chronic widespread pain</td>
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<tr>
<td>FIOH</td>
<td>Finnish Institute of Occupational Health</td>
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<tr>
<td>I</td>
<td>Intervention phase</td>
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<tr>
<td>ICC</td>
<td>Intraclass correlation</td>
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<tr>
<td>LBP</td>
<td>Low back pain</td>
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<td>MSD</td>
<td>Musculoskeletal disorder</td>
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<tr>
<td>MSP</td>
<td>Multiple-site musculoskeletal pain</td>
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<tr>
<td>OA</td>
<td>Osteoarthritis</td>
</tr>
<tr>
<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>Org -</td>
<td>No organizational reform</td>
</tr>
<tr>
<td>Org +</td>
<td>Organizational reform</td>
</tr>
<tr>
<td>PE</td>
<td>Participatory ergonomics</td>
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<tr>
<td>PI</td>
<td>Post-intervention follow-up phase</td>
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<td>PIA</td>
<td>Post-intervention assessment (at the end of the intervention)</td>
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<td>PI_{12}</td>
<td>The 12-month post-intervention follow-up</td>
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<tr>
<td>PR</td>
<td>Prevalence rate</td>
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<tr>
<td>RCT</td>
<td>Randomized controlled trial</td>
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<td>RR</td>
<td>Relative risk</td>
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1. INTRODUCTION

Musculoskeletal disorders (MSDs) are an important and costly occupational health problem with consequences for workers, employers and society. About 40 million workers are affected by work-related MSDs. Almost a quarter of the European workforce report that they have experienced muscular pain in their neck, shoulders and upper limbs, and about one in every three suffers from low back pain (LBP). Within the European Union, MSDs are the single most common cause of sickness absence from work, early retirement, and disability payments. It is estimated that the direct annual costs of the MSDs account for 2% of the European gross domestic product (Bevan et al. 2009).

There is a consensus that the etiology of MSDs is multifactorial. There has been a special emphasis on the effect of physical workload (awkward working postures, forceful movements, repetitive work, etc.) on MSDs. However, recently the role of psychosocial factors at work has become a focus of epidemiologic research. Several psychosocial factors have been found to associate with the occurrence of MSDs, e.g. low job satisfaction, high job demands, low job control, and low workplace social support. However, most of the evidence is based on cross-sectional studies. Cross-sectional studies are valuable if one wishes to elucidate associations between variables, but they do not usually provide information about the time sequence of the 'explanatory' and 'outcome' variables. Thus, the need for conducting more longitudinal studies has been emphasized.

In recent years, several studies have observed that multiple-site musculoskeletal pain (MSP) is even more frequently reported than any single-site pain. It has been suggested that the basic expectation should be that one regional pain accompanies another, irrespective of pain site (Croft et al. 2007; Croft 2009). Recently, Swedish researchers in their population based (n=2329) five-year follow-up study concluded, that having concurrent low back and neck-shoulder disorders was associated with a higher risk for sickness absence [odds ratio, (OR) 1.7)] as well as a risk for long-term sickness absence (OR 2.5) compared to having only low back or only neck-shoulder disorders (Nyman et al. 2007). The majority of studies to date have concentrated on pain and its risk factors at a
specific site, most often in the low back, and the risk factors of MSP are not well known. The need to study the co-occurrence of pain over time and to provide information on why pain tends to occur at multiple sites has recently been emphasized.

Preventive ergonomics interventions are widely applied in order to deal with MSDs. However, evidence on which of the interventions are the most effective is lacking. The participatory ergonomics (PE) approach is commonly recommended when the goal is to reduce MSDs, and its potential as an effective means to improve unsatisfactory psychosocial working environment has been emphasized. However, few high quality studies have been reported and evidence on the effectiveness of PE is scanty. It has been stated that a robust knowledge on the effectiveness of interventions must be based on several comparable high quality studies in which the effect of ergonomics interventions on the prevention or reduction of the MSDs has been rigorously evaluated (Bongers 2009). With respect to LBP prevention, The European Guidelines Working Group recently concluded that there is an urgent need for good quality randomized controlled trials (RCT) to examine the effectiveness of physical, psychosocial and organizational ergonomics interventions (Burton et al. 2006).

The studies described in this dissertation are part of a larger research programme entitled 'Effectiveness of an ergonomics intervention - a randomized controlled trial' (ERGO-study) conducted by the Finnish Institute of Occupational Health (FIOH) during the years 2002-2005 in collaboration with municipal kitchens in four large cities in Finland. This thesis reports the effects of the PE intervention on MSDs and on psychosocial factors at work and mental stress as intermediate outcomes of the intervention (studies I-II). In addition, the occurrence of MSP and associations of MSP with psychosocial factors at work over time are presented (studies III-IV).
2. REVIEW OF THE LITERATURE

2.1. Burden of musculoskeletal disorders

MSDs constitute a major public health problem in the industrialized countries. MSDs cause individual suffering, trouble in daily living, and considerable economic and societal consequences due to short- and long-term work disability and productivity losses (Norlund and Waddel 2000; Baldwin 2004; Buckle 2005). Low back pain, neck pain and shoulder disorders are common among working populations and are the main reasons for work-related consultations in general practice (Weevers et al. 2005; Taimela et al. 2007).

In general population studies in different countries, the lifetime prevalence of back disorders has varied between 30% and 84% and that of neck disorders has been about 70% (Riihimäki 2005a). According to representative samples of the Finnish population, chronic low back and neck disorders have decreased in both genders during the last two decades of the 20th century (Kaila-Kangas 2007). Still, the lifetime prevalence of back pain was as high as 76% among women and 77% among men, and that of neck pain 68% among women and 54% among men. The respective one-month prevalence figures of back pain were 33% and 28%, of neck pain 37% and 24%, of shoulder pain 23% and 18%, of hip pain 12% and 8%, and of knee pain 21% and 18%. A recent survey based on self-reported data from European workers claimed that about 33% of Finnish workers reported work-related pain in their neck, arms and shoulders. In the descending order of pain reporting, the Finnish workers ranked as the eighth of all EU member states (Bevan et al. 2009).

According to Finnish statistics in 2007, MSDs were the most common reason for receiving sickness absence benefits accounting for a total of 35% of all absence periods. There were almost 126 000 incident sickness allowance periods due to MSDs in 2007. The resulting benefit expenditures were about 273 million euros making up 36% of all the benefits. With respect to disability pensions, 24% were due to MSDs. Both the numbers of sickness benefit days and disability pensions were more common in women (Finnish Centre for Pensions 2008; The Social Insurance Institution 2008). The direct and indirect costs due to musculoskeletal pain in Finnish primary health care were about 1 billion euros and when
combined with costs due to permanent work disability, the overall losses were estimated to amount to 3% of the gross domestic product (Mäntyselkä et al. 2001; Mäntyselkä et al. 2002). In all 27 EU Member States, MSDs are the main cause of absence from work, and in some countries 40% of the costs of workers' compensation are attributable to MSDs (Podniece 2008).

**Multiple-site musculoskeletal pain**

Concomitant pain in several sites seems to be common. About three quarters of people report more than one site of pain, with a median count of three out of a possible count of ten (Croft 2009). The definition for MSP is not well established. The American College of Rheumatology (ACR) has developed a definition for chronic widespread pain (CWP). This definition requires the presence of pain that has been present for at least three months in the axial skeleton, above and below the waist, and on the left and right side of body (Wolfe et al. 1990). However, pain in multiple body sites that does not meet these classification criteria may also deserve attention. For example, MSP might have a stronger impact on mental health, quality of life and healthcare utilization than single-site pain, irrespective of whether or not the pain experienced by individuals satisfies the criteria for CWP (Davies et al. 1998; Carnes et al. 2007).

Several studies have reported that MSP is even more frequent than single-site pain both in the general population (Picavet and Schouten 2003; Walker-Bone et al. 2004; Carnes et al. 2007; Kamaleri et al. 2008c) and in occupational groups (Molano et al. 2001; Yeung et al. 2002; Alexopoulos et al. 2004; Ijzelenberg and Burdorf 2004; Solidaki et al. 2010). In the Dutch population, single-site pain during the past 12-months was reported by 25% of the sample, while 29% reported pain in 2-3 sites and 21% in four or more sites (Picavet and Schouten 2003). Among the Norwegian population, the respective proportions of subjects with pain during the past seven days were 17%, 27% and 27% (Kamaleri et al. 2008c). Carnes et al. (2007) found that over three quarters of a British sample who reported pain suffered from pain stemming from multiple sites.

Having pain at one site has been shown to increase the risk of developing pain at other sites and the risk seems to increase with the number of pain sites at baseline (Croft et al. 2007; Kamaleri et al. 2009). MSP was associated with decreased level of functional ability
among employees of the City of Helsinki (Saastamoinen et al. 2006) and a sample of the Norwegian general population (Kamaleri et al. 2008c). Among a representative sample of Finnish adults, the odds ratio of poor perceived physical work ability and the respondent's own prognosis of poor future work ability increased from two for single-site pain up to eight for pain at four sites (Miranda et al. 2010). MSP has been shown to predict both short- and long-term sickness absence (Natvig et al. 2002; Morken et al. 2003; Nyman et al. 2007) and permanent work disability (Kamaleri et al. 2008b). MSP commonly co-occurs with other syndromes (Aggarwal et al. 2006; Hagen et al. 2006) and is associated with poor mental vitality (Walker-Bone et al. 2004; Hagen et al. 2006). MSP is a persistent phenomenon and it predicts the risk of a current problem for becoming chronic (Papageorgiou et al. 2002; Andersson 2004; Kamaleri et al. 2009).

MSP is common already of school age and in adolescence (Jones et al. 2003; Adamson et al. 2007; Larsson and Sund 2007; Auvinen et al. 2009; Paananen et al. 2010). Thus, in schoolchildren the one-month prevalence of MSP has varied between 8% (Adamson et al. 2007) and 15% (Jones et al. 2003), depending on the criteria used for MSP and the age of the studied group. The average number of pain sites appears to be settled by age 20 and little variation seems to occur thereafter (Croft 2009; Kamaleri et al. 2009).

Based on this knowledge, MSP seems to be more disabling and more severe compared to local pain and it is a special challenge for occupational and health care professionals. Nonetheless, the majority of studies examining the occurrence and prognostic factors of musculoskeletal pain have focused on a specific anatomical site (Mallen et al. 2007) and the risk factors of MSP are inadequately understood.

### 2.2. Risk factors for musculoskeletal disorders

MSDs are the single largest category of work-related illness, representing a third or more of all registered occupational diseases in the Nordic countries, the United States and Japan. It has been estimated that about 40% of all upper limb disorders in the total US employed population were attributable to occupational exposures (Punnett and Wegman 2004). In global terms, 37% of LBP appear to be caused by occupation, and work-related
LBP has been estimated to be responsible for 818,000 disability-adjusted life years being lost annually (Punnett et al. 2005). Accordingly, risk factors related to work have been extensively studied. The World Health Organization has defined 'Work-related musculoskeletal diseases' as diseases that can be partly caused by adverse working conditions, or which may be aggravated, accelerated or exacerbated by workplace exposures, or such that may impair working capacity (WHO 1985).

Epidemiologic evidence has accumulated that both physical and psychosocial factors at work and individual factors play a role although the mechanisms involved in the development of MSDs are not yet completely understood. These factors interact, they may reinforce each other and their effects may be mediated by cultural or societal factors. All of them vary over time from one situation to the next, complicating attempts to clarify their relationships with the development of MSDs (National Research Council 2001; Bongers et al. 2006; Marras et al. 2009). Psychosocial risk factors for work-related MSDs can be categorised into those that are specific to the workplace (low social support at work, job satisfaction, low skill discretion, low job control etc.) and those that are individual psychosocial or psychological characteristics, such as depression, anxiety and mental stress (Sauter and Swanson 1996; Bernard 1997; National Research Council 2006). Non-workplace factors, which contribute to work-related MSDs possibly influencing individual responses to workplace exposures, are considered as individual factors. Among these, gender, age, education, marital status, weight, height, overweight/obesity, smoking, exercise or sports, other hobbies, drug use, personality, and various comorbidities (Bernard 1997; Burdorf and Sorock 1997; National Research Council 2001; Buckle and Devereux 2002; Cole and Rivilis 2006).

The following section will contain an overview of the risk factors of MSDs these being mainly based on existing review articles. The electronic databases Pubmed and Scopus were searched.
2.2.1. Physical workload

Low back disorders
The reviews on the relationship of physical workload with low back disorders by Hoogendoorn et al. (1999) and Hansson and Westerholm (2001) were based on cohort and case-control studies. The former covered studies from the period 1949-1997 and the latter with publications from 1971-2000. A recent review (Bakker et al. 2009) considered cohort studies only from years 1997-2007. The reviews indicate that the evidence is strong for manual materials handling, bending and twisting postures at work, and whole body vibration as being risk factors for LBP. With respect to patient handling, the evidence is moderate. Furthermore, the evidence is strong on standing, walking, and sitting at work for not increasing the risk of LBP. The summary of the review of Lis et al. (2007) claimed that prolonged merely sitting did not increase the risk of LBP, whereas sitting more than half of a workday in combination with whole body vibration and/or awkward postures did increase the risk. However, these conclusions were based mostly on cross-sectional studies. A review by Chen et al. (2009), based on 10 prospective cohort and 5 case-control studies, confirmed that sedentary life style (at work and leisure time) was not a risk factor for LBP.

Neck and upper limb disorders
The Bone and Joint Decade Task Force has recently summarized the determinants of neck pain among the working (Côté et al. 2008) and the general populations (Hogg-Johnson et al. 2008). Both reviews examined the literature from 1980 to 2006. These reviews are the first in which a sufficient number of cohort studies were available to allow reliable conclusions to be drawn. The best evidence synthesis among the working population was based on 19 cohort studies and 1 RCT. The following risk factors of neck pain were identified: prolonged sitting, repetitive and precision work, prolonged neck flexion, elbow and shoulder posture while working at a computer, inadequate mouse and keyboard position, and use of telephone shoulder rests. Preliminary evidence was found that awkward work postures, poor physical work environment, and exposure to glare might be associated with neck pain.
Some reviews have concluded that repetitive work and static work with arms abducted or elevated at more than 60 degrees are associated with shoulder disorders (Bernard 1997; Hansson and Westerholm 2001; Walker-Bone and Cooper 2005). Potential risk factors include also heavy workload and vibration (van der Windt et al. 2000). In a survey with a 20-year follow-up among the Finnish general population, work exposure to repetitive movements at baseline increased the risk of incident shoulder disorder with an OR of 2.3 and exposure to vibration with an OR of 2.5. These adverse effects were seen even among those older than 75 years at follow-up (Miranda et al. 2008a). Hagberg (2002) reviewed experimental and epidemiological studies and concluded that the scientific evidence is weak for vibration per se as a risk factor for MSDs, although job tasks with vibrating tools are associated with MSDs. In a two-year prospective study among newly employed workers (Harkness et al. 2003), lifting heavy weights with one or two hands, carrying on one shoulder, lifting at or above shoulder level and pushing and pulling were predictive factors of new onset shoulder pain.

Two recent reviews have summarised the literature on risk factors related to the carpal tunnel syndrome (CTS). The occurrence of CTS was associated with high levels of hand-arm vibration, prolonged work with a flexed or extended wrist, high requirements of hand force (> 4 kg), high repetitiveness (cycle time < 10 seconds, or performing the same movements for > 50% of cycle time), and their combination (van Rijn et al. 2009). Previously Palmer at al. (2007a) had found evidence that regular and prolonged use of hand-held vibratory tools doubled the risk of CTS. There was also substantial evidence found for similar or even higher risks from prolonged repetitive flexion or extension of the wrist, especially in combination with a forceful grip. Repetitive movements, use of hand force, non-neutral wrist postures, and their combinations, all seem to be associated with epicondylitis and hand/wrist tendinitis (Bernard 1997; Hansson and Westerholm 2001). However, most studies on occupational risks of tenosynovitis and epicondylitis have been criticized since they have been based on job titles rather than specific physical activities at work (Palmer et al. 2007b).
Lower limb disorders
According to D’Souza et al. (2005), few reports exist on occupational factors and disorders of the lower limbs other than osteoarthritis (OA), but it appears that standing and heavy physical workload may be associated with ankle and foot pain and plantar fascitis. A history of occupational activities involving prolonged standing may be associated with chronic plantar heel pain (Irving et al. 2006). Heavy physical work demands have increased the prevalence of knee complaints in repeated surveys among male employees in the Netherlands (deZwart et al. 1997). However, in a prospective study of forestry workers, no work-related factors predicted incident knee pain (Miranda et al. 2002).

Moderate to strong evidence exists that high physical workload is a risk factor of hip and knee OA (Bierma-Zeinstra and Koes 2007). Recently Jensen (2008b; a) made a best evidence synthesis evaluating the associations between hip and knee OA with more details about physical work demands. With respect to hip OA, moderate to strong evidence was found for heavy lifting, but the burdens have to be at least 10-20 kg and the duration of exposure at least 10-20 years to clearly increase the risk of hip OA. For example, for farmers the risk seems to double after about 10 years of farming. With regard to knee OA, evidence was moderate for a relationship of kneeling and heavy lifting and moderate for the combination of kneeling/squatting and heavy lifting. Insufficient or limited evidence was found for climbing stairs or ladders as causes of either hip or knee OA. There were limitations in some of the studies, e.g. small sample size, poor description of exposure, and the use of differing diagnostic criteria.

Multiple-site pain
Knowledge on risk factors for MSP is based on single studies since no systematic reviews are available. In dentists, a high perceived physical workload was associated with the co-occurrence of musculoskeletal pain at different sites (Alexopoulos et al. 2004). In a study of nurses, office workers, and postal clerks (Solidaki et al. 2010) the association was examined with the number of pain sites and a physical demands score which was based on heavy lifting, working with hands above the shoulder level, repeated bending of the elbow, repeated hand-arm movements, and kneeling, squatting or climbing stairs. In the multivariate analysis, the score had a strong graded relationship with the number of pain sites. Lifting of loads (>15 lbs) with one hand or with two hands (> 24 lbs), pulling (> 56
lbs), prolonged squatting, and prolonged working with hands at or above shoulder level were associated with the onset of widespread pain in a two-year prospective study among newly employed workers (Harkness et al. 2004). In a three-year follow-up study among a sample of adults in Manchester, Great Britain, pushing/pulling heavy weights, repetitive wrist movements, and kneeling were associated with the onset of CWP (McBeth et al. 2003). Repetitive movements of the arm or wrists predicted [relative risks (RR) 4.1 and 3.4] future episodes of forearm pain that commonly co-occurred with other regional pain (Macfarlane et al. 2000).

2.2.2. Psychosocial factors at work

Several reviews on associations of psychosocial factors at work with MSDs have been published during the past decade. Many psychosocial factors at work have been found to be associated with the occurrence of MSDs, such as rapid work pace, monotonous work, low job satisfaction, low workplace social support, high job demands, low job control, work stress, non-work-related stress, and high and low skill discretion (Davis and Heaney 2000; Hoogendoorn et al. 2000; Ariëns et al. 2001; Linton 2001; Bongers et al. 2002; Bongers et al. 2006). However, the conclusions of the reviews tend to be inconsistent with most of the evidence being based on cross-sectional studies. The review by Hartvigsen et al. (2004) only considered prospective studies and concluded that there was moderate evidence of no association between LBP with perception of work, organizational aspects, and social support at work; with respect to stress at work, the evidence was insufficient.

Macfarlane et al. (2009) evaluated the evidence on associations between psychosocial factors at work and MSDs based on published reviews. With regard to back pain, the conclusions were the most consistent for an association with high job demands, low job satisfaction and low work support. For neck/shoulder pain, consistency in conclusions was found both regarding high work demands (four reviews out of six reported an association) and for low job demands (two out of three reviews found an association). For lower limb disorders, there appears to be only a single review regarding knee pain. Subsequently, a review of studies among the working population (Côté et al. 2008) concluded that high job demands, low social support at work and job insecurity are risk factors for neck pain. Preliminary evidence was found for poor job satisfaction, stress at work and frequently
experiencing technical problems with a computer. van Rijn et al. (2009) found no association between any psychosocial risk factors and CTS.

**Multiple-site pain**

In the review of Mallen et al. (2007), low social support was one of the 11 generic prognostic factors associated with at least two regional pain complaints. In a population based study, dissatisfaction with support from colleagues or supervisors was observed to increase the risk (RR 4.7) of future episodes of forearm pain that commonly co-occurred with other regional pain (Macfarlane et al. 2000). Poor social relationships at work and poor job control predicted the increase of pain and clinical findings in the neck and upper limbs, low back, and lower limbs in a 10-year follow-up of industrial workers (Leino and Hänninen 1995). Adverse work-related psychosocial factors and high levels of individual psychological distress predicted the onset of musculoskeletal pain at a one-year follow-up with similar effects across the anatomical sites (Nahit et al. 2003). In a two-year prospective study among newly employed workers, those who reported low job satisfaction, low social support and monotonous work had an increased risk of new-onset widespread pain (Harkness et al. 2004).

Leino and Magni (1993) conducted a 10-year follow-up study among employees in the engineering industry and found that symptoms related to mental stress predicted an increase in a sum score of musculoskeletal pain at several sites, and that the pain sum score predicted an increase in stress symptoms.

**2.2.3. Health-related lifestyle**

Shiri at al. recently published two meta-analyses on the relationships of overweight, obesity and smoking with LBP (Shiri et al. 2010a; b). Overweight and obesity increased the prevalence of LBP. The associations were strongest for seeking care for LBP (pooled OR 1.6) and chronic LBP (OR 1.4). Obesity also increased the incidence of LBP (OR 1.5). The findings pointed to stronger associations in women than in men. Both current and former smokers were observed to have a higher prevalence and incidence of LBP than never smokers, with the associations being strongest for disabling (OR 2.1) and chronic (OR 1.9) LBP. Male smokers were at a higher risk of LBP than female smokers. In their
previous systematic review, Shiri at al. (2007) concluded that overweight, long smoking history, high physical activity and a high serum C-reactive protein level were associated with lumbar radicular pain and sciatica. In her review Kauppila (2009) found that smoking and high serum cholesterol levels were most consistently associated with disc degeneration and LBP. Miranda et al. (2008b) studied the one-year incidence of LBP according to age group in a Finnish industrial population. Health behaviour, defined as a sum score of overweight, smoking and lack of physical activity, increased the risk of LBP only among those 50 years or older (RR up to 2.8), whereas physical workload predicted LBP among those younger than that age.

Two recent systematic reviews published by Hogg-Johnson et al. (2008) and Côté et al. (2008) evaluated the determinants of neck pain. The former found evidence that exposure to passive smoking in adolescents increased the risk of neck pain. The latter review summarized that smoking increased the risk of neck pain among the working population. A review by Viikari-Juntura et al. (2008) reported some associations between body weight (weight, BMI) and shoulder disorders. Smoking was associated with shoulder disorders but only in studies examining occupational populations. Obesity is reported to be a risk factor for CTS (Walker-Bone et al. 2003; Hooper 2006) and hip and knee OA (Hooper 2006; Wearing et al. 2006; Bierma-Zeinstra and Koes 2007). In the systematic review of Irwing et al. (2006) increased BMI was associated with chronic plantar heel pain in a non-athletic population. Obesity may also have a profound effect on soft-tissue structures, such as tendons, fasciae, and the cartilage, in addition to being a risk factor for bone and joints disorders (Wearing et al. 2006).

There is moderate to strong evidence that high-intensity sporting activities are risk factors for hip OA (Bierma-Zeinstra and Koes 2007), but leisure time sports or exercise were not found to be risk factors of LBP (Hoogendoorn et al. 1999; Bakker et al. 2009). A Dutch research group (Hamberg-van Reenen et al. 2007) carried out the first review of the relationship between physical capacity and future LBP and neck/shoulder pain based on longitudinal studies. They found strong evidence that there is no relationship between trunk muscle endurance and the risk of LBP and inconclusive evidence for a relationship between trunk muscle strength and mobility of the lumbar spine and the risk of LBP. Evidence was inconclusive also for the associations between physical capacity measures
with the risk of neck/shoulder pain. Instead, Côté et al. (2008) claimed that low to moderate physical capacity of neck and shoulder musculature was associated with an increased risk of neck pain.

**Multiple-site pain**

Current smoking was associated with an increased risk of chronic pain in multiple locations and with CWP in both genders among the general rural population (Andersson et al. 1998). Smokers, overweight subjects and those with low physical activity have reported a greater number of pain sites (Walker-Bone et al. 2004; Kamaleri et al. 2008a). Jones et al. (2003) stated that high levels of sports activity predicted the onset of widespread pain among schoolchildren (RR 1.9). Finnish researchers have studied MSP among adolescents (Paananen et al. 2010). They found that a high physical activity level, long sitting time, short sleeping time, and smoking were associated with MSP in both boys and girls though the associations were stronger in girls. In addition, MSP was associated with overweight in girls.

**2.2.4. Individual factors**

Women tend to report more MSDs than men. The gender difference seems to be more distinct for neck and upper limb disorders (Hooftman et al. 2004; Strazdins and Bammer 2004). Strazdins and Bammer (2004) examined why employed women are much more likely than men to experience upper body disorders. The gender differences were explained by risk factors at work (repetitive work, poor ergonomic equipment) and at home (less opportunity to relax and exercise outside of work). Parenthood exacerbated the gender difference with mothers reporting having the least time to relax or exercise. The gender segregation of women into sedentary, repetitive and routine work and the persisting gender imbalance in domestic work were concluded to be interlinking factors that accounted for the gender differences in MSDs.

A Danish research group has recently published two large population based studies of twins aged 20-71 years (Hartvigsen et al. 2009; Leboeuf-Yde et al. 2009). A cross-sectional survey examined 34 902 twins (Leboeuf-Yde et al. 2009) and it showed that women were more likely to report MSDs and to have had pain for longer periods than
men. Neck pain and LBP was common already at the age of 20, with the prevalence increasing slowly with age until reaching a peak around middle age. Similar patterns were noted for radiating pain. Pain was reported to be more long lasting in the older groups. In the analyses of 15,328 twins, genetic susceptibility explained about 38% of lumbar, 32% of thoracic, and 39% of neck pain (Hartvigsen et al. 2009).

Other twin studies have suggested that both disc degeneration and back pain contain a genetic component. A variety of definitions of back pain problems have been used in genetic studies that could influence responses and heritability estimates since these have varied widely in the scientific literature, explaining from 0% to 57% of the variance in back pain reporting (Battie et al. 2007). A recent narrative review by Kalichman and Hunter (2008) reviewed knowledge of heritability of intervertebral disc degeneration. The review covered the literature from 1950 to 2007. Familial predisposition to disc degeneration was observed to be high. Heritability estimates ranged from 34% to 61% in different spine locations. Fejer et al. (2006) examined a large population based group of twins (n= 33,794) and noted that genes play a significant role in neck pain, particularly in women. The overall genetic effect of lifetime neck pain was observed to be 44%. There was a statistically significant difference in heritability between males and females (34% vs. 52%). However, the genetic effect became gradually less important with increasing age. In other words, environmental factors dominate almost completely in the older age groups. Hartvigsen et al. (2005) reported that genetic factors do not play an important role in the liability to neck pain in individuals 70 years of age or older. Previous musculoskeletal pain is a risk factor for neck pain and ethnicity is possibly associated with neck pain (Côté et al. 2008).

**Multiple-site pain**
MSP generally increases with age (Bingefors and Isacson 2004). Women have been shown to report a greater number of pain sites than men (Picavet and Schouten 2003; Walker-Bone et al. 2004; Kamaleri et al. 2008a) and this trend has been seen already in adolescents. Paananen et al. (2010) reported that 40% of girls and 23% of boys had experienced MSP during the past six months. Auvinen et al. (2009) found that the prevalence of MSP during the past six months increased from 15% in girls and 9% in boys at the age of 16 years up to 27% and 15%, respectively, at the age of 18 years. Kamaleri et
al. (2009) observed a relative stable pattern of reporting the number of pain sites across adulthood. About 46% of the participants reported the same number of pain sites 14 years later, plus or minus one site. The average number of pain sites appears to be set by the age of 20. Little variation in the stability was seen by age or birth cohort, except for a small decline occurring between 60 and 74 years (Croft 2009; Kamaleri et al. 2009).

Genetic factors may be associated with reporting pain at multiple sites (Zubieta et al. 2003). In the Danish twin study (Hartvigsen et al. 2009), patterns of pain occurrence in three spinal regions (cervical, thoracic, lumbar) were examined. It was found that the heritability of having pain in all three areas was 35%, i.e. the highest of all combinations. Mikkelsson et al. (2001) examined the pattern of familial aggregation of widespread pain in 11-year-old Finnish twins. In girls 56% and in boys 35% of the variation in liability was accounted for by familial factors.

In summary, there is a considerable body of epidemiologic literature which has examined associations of physical workload with MSDs, particularly with back disorders. In addition, associations of psychosocial and individual factors with MSDs have been studied. However, prospective studies are in the minority and evidence is largely based on cross-sectional or case-control studies. This is particularly true of neck and upper limb disorders. There are few studies on lower limb disorders these being mainly concerned with hip and knee OA. Most of the existing evidence on associations of psychosocial factors at work with MSDs is based on cross-sectional studies. Although MSP is more common than single-site pain, the studies have typically examined separately at pain in different single anatomical sites and thus the risk factors for MSP remain largely unknown. However, it seems that single-site pain and MSP may share many predictive factors. A summary of findings on associations of physical and psychosocial risk factors with the various MSDs based on the literature is shown in Table 1.

Available evidence of risk factors suggests that workplace interventions aiming at reducing physical workload and improving psychosocial working conditions could have potential for the prevention of MSDs. In addition, interventions targeted to improve health behaviour (avoiding overweight/obesity and smoking) may be beneficial. There is varying evidence about the role of leisure time physical activity, and the role of physical capacity
as a protective factor for MSDs is unclear. More and more research addressing genetic factors in relation to MSDs has been conducted over the past decades, and evidence has accumulated that there are major genetic influences involved in the development of MSDs. Nonetheless, little is known about the roles of individual genes or the pathways and mechanisms through which they influence pain problems (Battié et al. 2007).

Table 1. Associations of work-related physical and psychosocial risk factors with MSDs, as based on literature. Osteoarthritis (OA), multiple-site pain (MSP)

<table>
<thead>
<tr>
<th>Physical workload¹</th>
<th>Low back</th>
<th>Neck</th>
<th>Upper limbs</th>
<th>Hip OA</th>
<th>Knee OA</th>
<th>MSP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual materials handling</td>
<td>+</td>
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<tr>
<td>Bending and twisting/awkward postures</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Whole body vibration</td>
<td>+</td>
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<tr>
<td>Patient handling/nursing</td>
<td>+</td>
<td></td>
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<tr>
<td>Prolonged sedentary work position</td>
<td>+</td>
<td></td>
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<td></td>
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<tr>
<td>Repetitive work</td>
<td>+</td>
<td>+</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Precision work</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Prolonged neck flexion</td>
<td>+</td>
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<tr>
<td>Upper extremity posture</td>
<td>+</td>
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<tr>
<td>Mouse/keyboard position</td>
<td>+</td>
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<tr>
<td>Static work/static work with arms abducted or/elevated more than 60 degrees</td>
<td>+</td>
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<tr>
<td>Heavy workload</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td></td>
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<tr>
<td>Vibration</td>
<td>+</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Repetitive movements</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td>Non-neutral wrist postures</td>
<td>+</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Use of hand force</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination of repetitive movements, use of hand force, non-neutral wrist postures</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifting</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kneeling</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Combination of kneeling/squatting, heavy lifting</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Pushing/pulling</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Prolonged squatting</td>
<td>+</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Prolonged working with hands at or above shoulder level</td>
<td>+</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Psychosocial factors at work²</th>
<th>Low back</th>
<th>Neck</th>
<th>Upper limbs</th>
<th>Hip OA</th>
<th>Knee OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>High job demands</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low job demands (monotonous job, insufficient use of skills)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low job satisfaction</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Low social work support</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td></td>
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<tr>
<td>Low job control</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor social relationships at work</td>
<td>+</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Stress at work</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adverse work-related psychosocial factors</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Job insecurity</td>
<td>+</td>
<td></td>
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</tr>
</tbody>
</table>

*Both physical and psychosocial risk factors for MSP were based on single prospective studies.
†Based on reviews: low back disorders (cohort and case-control studies), neck disorders (cohort studies, 1 RCT), upper limb disorders (mostly cross-sectional studies), hip and knee OA (mostly case-control and cohort studies). ‡Based on two reviews: one comprised of cohort studies and one RCT, the other was an overview of the reviews (most studies were cross-sectional).
2.3. Ergonomics intervention studies

In order to control and deal with the burden of MSDs, a variety of preventive ergonomics interventions have been conducted. Studies with rigorous designs and methods are needed in order to determine which of these are the most (cost) effective in reducing MSDs. Causal inference is often challenging in intervention research. If changes are observed, can these be attributed to the intervention? The ideal type of study in establishing causality in terms of internal validity is a RCT. The results of RCTs are considered as the 'gold standard' and the basis of 'evidence-based practice' in intervention research. Quasi-experimental studies are frequently used, when random assignment is not possible or feasible (Rothman and Greenland 1998; Grimshaw et al. 2000; Franceshi and Plummer 2005).

2.3.1. Study designs

Randomized controlled trials
In RCTs, individuals, and in cluster randomized trials (CRTs), groups of people or intact social units (e.g. workplaces, schools, medical practices, cities), are randomly allocated to an intervention or a control group. In CRTs, outcomes are measured on the individuals within clusters. CRTs are used to evaluate group interventions and individual interventions where group level effects are relevant. CRTs are also considered when the intervention is given to individuals but might affect others within that cluster. In the evaluation of complex interventions in which several factors may act interdependently at various levels of an organization and have an effect on many processes and outcomes, cluster designs may be useful (Donner and Klar 2000; Atienza and King 2002; Medical Research Council 2002).

The aim of randomization is to avoid confounding and selection bias by creating comparable groups with respect to any known or unknown potential confounding factors. A control group is needed to differentiate between change and effect. The prospective design with at least one measurement before and at least one after the intervention makes it possible to study changes over time. The effect is estimated by comparing what happened in the intervention group with what happened to those without the intervention.
Blinding and use of placebo treatment are other methodological advantages offered by RCTs. The purpose of blinding is to eliminate bias resulting from the expectations of participants or researchers with respect to outcomes. In single-blind trials, it is either the participants or the researchers who are unaware of the results of the randomized assignment. In double-blind trials, neither the participants nor the researchers or those administering the interventions and assessing the outcomes (care providers, outcome assessors) know who belongs to the control and the intervention group. Placebo treatment is important to distinguish the effect of a specific intervention from the effect of a sham intervention. Unfortunately, blinding and use of the placebo are commonly impossible in ergonomics and other workplace interventions (Shannon et al. 1999; Jüni et al. 2001; Buring 2002; Green 2002; Kristensen 2005).

When compared with an individually randomized trial, the CRT is more complex to design and it requires more participants to obtain equivalent statistical power. The power of a CRT depends more on the number of groups randomized rather than on their size. The number of groups randomized should be large enough in order to yield similar distributions of baseline characteristics among the groups. Since participants within a cluster are more likely to have similar outcomes, the outcomes are not completely independent. This clustering effect and variation within and between clusters must be taken into account in the statistical analyses (Rothman and Greenland 1998; Campbell et al. 2000; Donner and Klar 2000; Atienza and King 2002; Green 2002; Medical Research Council 2002; Campbell et al. 2004). Reporting of CRTs requires additional consideration, and an extended CONSORT statement including a checklist of items that should be included in the trial report, has been published (Campbell et al. 2004).

**Quasi-experimental designs**

In *controlled before-after studies* (pre-post / post-only non-equivalent control group design), the groups are assigned to intervention and comparison groups without random assignment. It is important that there should be minimal differences between the intervention and control group at baseline regarding the outcome measures, confounding factors and other variables thought to influence the estimation of the effect of the intervention. The major problem with such a design is that the groups might not be the similar before the intervention. *Uncontrolled before-after studies* (the pre-post/ post-only
one-group designs) with no random assignment and no comparison group are the weakest designs. In these studies, it is difficult or impossible to attribute changes in the outcome to the intervention (Shannon et al. 1999; Grimshaw et al. 2000).

Study design quality has been observed to be inversely associated with the reported magnitude of effects; it seems that the more rigorous the study design, the weaker the effects which can be found (Volinn 1999; Grimshaw et al. 2000; Neumann et al. 2010). The effects based on uncontrolled before-after studies have been larger than those based on controlled before-after studies. In randomized studies, the effects have been smaller than in studies using quasi-experimental designs.

2.3.2. Methodological issues

Internal and external validity in randomized trials
In RCTs, internal validity is threatened by several sources of bias. Selection bias may occur if there is an error in the allocation of individuals or groups to the intervention and control groups. The researchers may have conscious or attitudinal preferences with respect to the allocation, the consequences of which are avoided if the allocation sequence can be generated by using a computer algorithm. The allocation sequence must be concealed from the researchers enrolling the participants. Dropouts may lead to increasingly different groups (attrition bias) if those who drop out are systematically different from those who remain in the study. Unequal additional interventions distinct from the intervention under evaluation (performance bias), and an influence by a knowledge of the subjects' assignment on the assessment of outcome (detection bias) are other threats to internal validity in randomized designs (Jüni et al. 2001).

There are further potential influences that can diminish the effect of an intervention. The subjects in the control group may also receive the intervention (contamination), e.g. when participants move from one group to another during the intervention. Non-compliance occurs when subjects in the intervention group do not follow the intervention protocol, i.e. they do not 'take the pill' that they are supposed to take. The 'Hawthorne effect' refers to the possibility that the behaviour of the subjects in the intervention group may alter simply
because they consider that they are under observation (Shannon et al. 1999; Jüni et al. 2001; Buring 2002; Green 2002; Kristensen 2005).

External validity refers to the generalisability of the results. Causal inference based on a study has external validity if it can be transferred from the study's unique settings to other situations: other subjects, populations or workplaces. Information pertinent to the assessment of external validity includes a detailed description of participants (age, gender, occupation, work experience etc). The manner of recruitment (volunteers vs. all workers) is relevant, since results obtained from volunteers are often not generalizable to the wider population. The number of dropouts and the differences between them and non-dropouts should be reported. Details of the intervention process and content need to be explicitly described to enable the assessment of external validity. Contextual factors should be considered as they can have an influence on the effectiveness of an intervention. As an example, an ergonomics intervention might have a larger impact on a workplace where ergonomics has not been considered compared to the situation in a workplace where attention has already been paid to ergonomics (Goldenhar and Schulte 1996; Shannon et al. 1999; Jüni et al. 2001).

**Study quality**

In the literature, various proposals for improvement of study quality will be put forward. Intervention studies should preferably have a theoretical basis that includes a model of the possible causal processes involved. If there is no knowledge or theory on the links between the intervention and the desired outcome, it is difficult to understand how an intervention works (Goldenhar and Schulte 1996; Shannon et al. 1999; Kristensen 2005).

Attention should be paid to the selection of samples, adequate sample size, and duration, exposure to and intensity of intervention (Goldenhar and Schulte 1996; Buring 2002; Green 2002; Silverstein and Clark 2004; Kristensen 2005). In order to detect changes in outcomes, a sufficiently long enough follow-up is needed due to latency periods in the development of MSDs. No absolute limits can be set, but a follow-up time of one year, or at least six months, has been proposed (Westgaard and Winkel 1997; Driessen et al. 2010). Since the latencies are for the most part still unknown, it is recommended that multiple follow-ups should be attempted if feasible, and both short- and long-term effects should be
measured (Karsh 2006). Valid and reliable measurements are needed to ascertain whether the intervention was carried out as intended, whether the intervention led to the intended changes in exposure, and whether the changes in exposure led to the anticipated effect on health outcomes (Kristensen 2005). With all interventions, but especially when using a multiple-component intervention, measurement and reporting on the effects of the intervention on intermediate outcomes needs to be emphasized (Karsh et al. 2001). Measurements of potential confounders or effect modifiers, appropriate and adequate statistical methods and accounting for losses to follow-up are needed. Analyses should follow an intention-to-treat principle, i.e. regardless of whether or not the intervention is completed or received, the subjects or clusters are kept in their original groups. Evidence of compliance with the intervention, potential contamination between the groups, and co-interventions also need to be considered (Buring 2002; Green 2002; Silverstein and Clark 2004).

**Process evaluation**

A careful evaluation of the intervention process is important, based on a systematic documentation of how the intervention was carried out. This can help in the interpretation of the study findings and explain how and why changes were or were not achieved. The evaluation provides feedback for improving the intervention in the future. The results can be used when the intervention is repeated in another setting and help others to avoid pitfalls (Goldenhar et al. 2001). It is important to detect if the intervention, even one deemed effective, was not fully implemented such that not all participants were exposed to it (programme failure) or whether it worked poorly although all participants were involved (theory failure) (Kristensen 2005).

**2.3.3. Challenges encountered in workplace intervention studies**

Executing controlled intervention studies in workplaces is difficult. It is also time-consuming and costly (Schulte et al. 1996; Volinn 1999; Karsh et al. 2001). Worksites with a large number of workers doing the same tasks largely belong to the past and studies are confronted with unplanned changes beyond the researchers' control. Workforce or manager turnover must be taken into account. Rapid business or market plan changes, and changes in production processes that influence work assignments and exposure levels may
occur and these are largely unforeseen when the intervention is being planned (Cole et al. 2003; Silverstein and Clark 2004; Heaney and Fujishiro 2006).

It is essential that workplaces approve of the intervention study and perceive that they will gain benefits from participating in it. Both management and workers should comply with the concept of random assignment between an intervention and a control group. This is not always the case. Workplaces participating in an intervention and believing that it will be effective might have difficulties to accept the use of a control group. If the intervention being tested is believed to be effective, it might be difficult for the workplaces to justify having a control group due to financial aspects (Braunholtz et al. 2001; Karsh et al. 2001; Kristensen 2005). Those outside the trial should not receive inferior care simply because of not being in the trial. Thus, close collaboration, adequate communication, and mutual commitment between researchers, workers and management are all necessities. The successful conduct of an intervention requires interdisciplinary teams, in which understanding and respect between disciplines can promote the ability to meaningfully work together (Schulte et al. 1996; Kristensen 2005).

2.3.4. The participatory approach

The participatory method is commonly used in the design and analysis of work systems (Brown 2005) and its advantages have been discussed especially in relation to PE (Kogi 2006). Along with an increased utilization of participatory methods, it has been recognised that ergonomics experts alone cannot achieve successful and widespread implementation of ergonomics in the workplace (Haines and Wilson 1998; Kogi 2006). PE is a complex and ambiguous concept. No general agreement about the term exists (Haines and Wilson 1998). Wilson and Haines (1997) have proposed that PE refers to 'the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals'. Imada (1991) defines PE as 'a macroergonomic approach to the implementation of technology in organizations that requires end users to be highly involved in developing and implementing the technology' and Nagamashi (1995) as 'the workers active involvement in implementing ergonomic knowledge and procedures in their workplace supported by their supervisors and managers, in order to improve
working conditions and product quality' whereas Kuorinka (1997) considers PE as 'practical ergonomics with participation of the necessary actors in problem solving'.

A characteristic of most PE interventions is the formation of some type of team or committee consisting of workers or their representatives, managers, health and safety personnel, ergonomists, and sometimes research experts. This team usually receives training in ergonomics from an expert to become familiar with ergonomic principles, workplace specific risk factors and how this knowledge can instigate improvements (Theberge et al. 2006; IWH 2008; van Eerd et al. 2008). The expert may also give training in interpersonal, communication and team-building skills. The expert may function as a resource person, i.e. an individual familiar with the available skills and knowledge to help in problem-solving and who can contribute to the design of the intervention. The role of the expert is varied and complex but in all participatory approaches he/she acts as an agent or facilitator of change (Brown 2005).

Furthermore, a successful PE program requires that the responsibilities of team members in problem-solving, and developing and implementing changes, are well defined, that the group makes decisions through group consultation and that the management is involved in any decision requiring resources and implementation. Support, time and financial resources from the top levels of management are key factors in the success (IWH 2008; van Eerd et al. 2008).

The PE approach has several advantages. When the workers are involved in the process as the best experts of their own work, a feeling of solution ownership is generated, leading to increased job satisfaction and commitment to the changes being implemented. Participation represents a learning experience for the individuals involved, as well as giving them more self confidence, competence and independence. It has been suggested that worker participation can play a role in reducing stress at work.

There can be disadvantages encountered in PE, e.g. the workers' unwillingness to participate, or the organizational structure may limit the degree of worker participation. True commitment from the top management may be difficult to obtain. The process may encourage workers to develop unrealistic expectations or it may provoke envy and
dissatisfaction among those not involved in the improvement process (Haines and Wilson 1998; Brown 2005).

2.4. Evidence of the effectiveness of ergonomics interventions in preventing musculoskeletal disorders

2.4.1. Overview

When the current intervention study was planned, the scientific literature was scrutinized, coming the conclusion that no high-quality studies had been reported on the effectiveness of ergonomics interventions and that sound evidence was lacking (van Poppel et al. 1997; Westgaard and Winkel 1997; Volinn 1999; Lincoln et al. 2000; Linton and van Tulder 2001). In recent years, a few RCTs have been reported and the number of systematic reviews in this area has increased. Most of the studies have focused on behavioural (e.g. physical training of the worker, advice or education about working methods and techniques or the use of personal protective equipment) and physical interventions (e.g. redesign of physical work environment, working aids or tools, lifting and transfer aids for manual materials handling), whereas organizational intervention studies are still sparse. Organizational interventions occur at company, job or task level and focus on work processes, practices, and policies of workplaces (i.e. job rotation, job enlargement, modification of the production system). Such interventions often have an impact on both physical and psychosocial load of the workers (Goldenhar and Schulte 1996; Westgaard and Winkel 1997; Zwerling et al. 1997). The PE approach is recommended to reduce MSDs (Cole et al. 2005; Hignett et al. 2005; van der Molen et al. 2005a; Rivilis et al. 2006; Rivilis et al. 2008) and its potential as an effective means to improve unsatisfactory psychosocial work factors has been emphasized (Haims and Carayon 1998; Heaney and Fujishiro 2006; St-Vincent et al. 2006). It has also been claimed to be the most efficient way to improve ergonomics in the workplace (Hagberg et al. 1995). However, evidence on its effectiveness continues to be scanty. In multi-component interventions, different intervention types are combined (Feuerstein et al. 2000; Karsh et al. 2001; Gatty et al. 2003). They might have a greater chance of success than single interventions in preventing MSDs (Karsh et al. 2001; Gatty et al. 2003; Silverstein and Clark 2004; Tveito et al. 2004;
Cole et al. 2006), but it is not possible to recommend which components should be included and how they should be balanced (Burton et al. 2006).

Despite the increasing number of studies, they seem mostly to suffer from low methodological quality. All the reviews have concluded that good quality RCTs are urgently needed to provide convincing evidence on the effectiveness of the interventions. Burton et al. (2006) highlighted the need for conducting especially CRTs targeted to study the effectiveness of physical, psychosocial and organizational ergonomics interventions.

This literature review is mainly based on recent systematic reviews. In addition, some original randomized or non-randomized studies will be described. Interventions using the PE approach are reviewed separately. Tertiary prevention interventions were excluded because they are beyond the scope of this thesis. The reviews were favoured in which the authors had used some of the several guidelines developed for the reporting and a quality assessment of studies, e.g. the Delphi list (Verhagen et al. 1998), the GATE checklist (EPIQ 2004), or the criteria recommended by the Cochrane back review group (van Tulder et al. 2003).

2.4.2. Behavioural and physical interventions

Low back pain

Back schools are not recommended for the prevention of LBP (Linton and van Tulder 2001, Burton et al. 2006, Bigos et al. 2009). The use of back belts, lumbar supports (Jellema et al. 2001; Linton and van Tulder 2001; van Poppel et al. 2004; Ammendolia et al. 2005; Bigos et al. 2009), and shoe inserts or orthoses have also been shown to be ineffective (Burton et al. 2006, Bigos et al. 2009). Training in manual materials handling or the use of lifting equipments is not effective if it is used as the only intervention (Bos et al. 2006; Martimo et al. 2008; Bigos et al. 2009). Training and education combined with the use of mechanical or other aids may be effective, which can be partly explained by a decrease in the frequency of manual lifting (Bos et al. 2006).

When technical lifting devices were part of a more comprehensive intervention, a reduction in physical work demands and low back disorders was found, particularly when the PE approach was used (van der Molen et al. 2005a). A recent systematic review by
Driessen et al. (2010) included only RCTs and surveyed studies from the time period 1988 to 2008. These investigators concluded that physical ergonomics interventions were not effective in the prevention of LBP. Thus, there seems to be insufficient evidence to recommended physical (or organizational) ergonomics interventions alone for the prevention of LBP (Linton and van Tulder 2001; Burton et al. 2006).

**Pain in the neck and upper limbs**

Intervention studies concerning neck and upper limb disorders are considerably less common than those on LBP. The systematic review of Brewer et al. (2006) examined articles published from 1980 to 2005. They found moderate evidence for a positive effect of alternative pointing devices and no effect of workstation adjustment, rest breaks, and exercise during the breaks among computer users. The systematic review by Driessen et al. (2010) showed that physical ergonomics interventions were not more effective on short and long term neck pain prevalence or incidence, but possibly could reduce the intensity of neck pain in the long run. However, the number of studies was limited and targeted mostly office workers, and populations, interventions and outcomes were heterogeneous. Boocock et al. (2007) reported moderate evidence that mouse and keyboard design led to positive effects in neck and upper limb conditions among video display unit (VDU) workers, but among manufacturing workers, the evidence was insufficient. Norwegian researchers have published protocols of Cochrane systematic reviews on workplace interventions for neck pain (and LBP), and it can be predicted that the results of these reviews will add to knowledge in this area in the near future (Aas et al. 2009a; Aas et al. 2009b).

**Lower limb pain**

No literature on the effectiveness of work-related interventions regarding lower limb pain was found.

2.4.3. **Organizational interventions**

A narrative review by Westgaard and Winkel (1997) and a systematic review conducted ten years later by Boocock et al. (2007) showed consistently that there was insufficient evidence for demonstrating any benefits of organizational interventions. In the latter review, only two relevant studies were identified. These involved no randomization, were
of low quality, and showed no improvements in outcome measures. Driessen et al. (2010) stated that RCTs on organizational ergonomics interventions to prevent and reduce neck pain and LBP were lacking. Many other authors have recently concluded that evidence on the effectiveness of organizational interventions is scanty (Murphy and Sauter 2004; Bongers et al. 2006; Burton et al. 2006; Heaney and Fujishiro 2006; St-Vincent et al. 2006; Podnieze 2008). Few studies exist on the effectiveness of work-rest schedules, breaks, task rotation and task enrichment, but the results are contradictory and no conclusive evidence is available (Bongers et al. 2006; Podnieze 2008). Two reviews have reported on the effects of workplace reorganization on psychosocial factors and health, with reference to the 'demand-control-support' model (Bambra et al. 2007; Egan et al. 2007). Limited and inconsistent evidence was found to support health benefits when employee control improved, demands decreased or support increased. Two studies of participatory interventions occurring alongside redundancies reported worsening of employee health (Egan et al. 2007). Task-restructuring interventions that increased demand and decreased control had an adverse effect on health, and an increase in workplace support did not appear to mediate this relationship (Bambra et al. 2007). van der Klink et al. (2001) reported a small and non-significant effect size for the few organizational interventions that were focused on work-related stress.

One CRT (Tsutsumi et al. 2009) and one non-randomized controlled before-after study (Kobayashi et al. 2008) have been published after the above mentioned reviews. They showed positive effects on improving mental health and job performance by using the participatory approach. These studies are reviewed below.

2.4.4. Participatory ergonomics interventions

Only one systematic review on the effectiveness of the PE interventions was found. Rivilis et al. (2008) used a best evidence synthesis where 12 studies were evaluated to be of sufficient methodological quality to be included. Nine 'medium' and three 'higher' quality studies showed partial to moderate evidence that the PE interventions had had a favourable impact on musculoskeletal symptoms and reduced workers' compensation claims and sickness absence. However, random allocation or adjustments for differences between groups at baseline were used only in three studies. Other methodological flaws
were insufficient documentation of participation in the PE process and poor reporting of consideration of potential confounders. In the studies graded as 'low' quality, also deficient reporting of co-interventions and of risk factor measurement at baseline and at follow-up, lack of comparison groups, and inappropriate statistical analysis were observed.

Seven RCTs were detected. Two studies (Straker et al. 2004; van der Molen et al. 2005b) were not included because they did not have musculoskeletal health or psychosocial factors at work as outcomes. Finally, three of the five RCTs were cluster randomized studies (one being still conducted), and two were individually randomized. Only two studies were organizational interventions specifically on mental health and psychosocial job conditions. The contents of the PE interventions are briefly described below. A more detailed summary of the reviewed original PE intervention studies and their results are presented in Table 2.

Non-randomized controlled before-after studies
Kobayashi et al. (2008) examined the effects of a participatory organizational intervention on job stressors and mental health among workers in a manufacturing company. A work environment improvement team supported each participating department throughout the six-month intervention. A checklist called the Mental Health Action Checklist for a Better Workplace Environment (MHACL) was designed for use in a group-based workshop that was arranged in the departments. In the workshops, workers were informed about stress and mental health at work and concepts related to improving work environments. Based on the MHACL, each group listed action items that might be useful for better worker mental health in their department. The team encouraged the implementation of the plans in each department after the workshops. Among women, skill underutilization, supervisor and co-worker support, psychological distress and job satisfaction developed significantly more favorably in the intervention group than in the control group. No such effect was observed among men, and no effect was observed on the number of sick leaves in either gender.

The group of Laing studied the effectiveness of a PE intervention in reducing worker pain severity through changes aimed at reducing physical demands (Laing et al. 2005) and improving communication and the psychosocial work environment (Laing et al. 2007) in
an automotive parts manufacturing factory. An ergonomics change team (ECT) was responsible for identifying the targets for ergonomic improvements and developing and implementing solutions based on the PE Blueprint (identification, assessment of ergonomic risk factors, solution building/testing, and implementation). The researchers supported the activities of the ECT during an 11-month period (1 month training, 10 months intervention). The ECT was trained to take into account basic anatomy, physical and psychosocial risk factors, and ergonomics principles and assessments tools. The intervention had no significant effect on the workers' mechanical exposures, perceived effort, perceptions of decision latitude, or pain severity levels. Communication dynamics regarding ergonomics was significantly enhanced in the intervention group compared to the control group.

The study of Rivilis et al. (2006) conducted in a depot of a large courier company shared similarities with the study of Laing et al. An ECT was responsible for the 14-month intervention that was based on the PE Blueprints. The ECT was trained in ergonomics, workplace risk factors, and the tools needed to perform ergonomic assessments. Greater participation in the intervention process was associated with increased levels of job influence and communication. Improvements in communication were associated with reduced pain intensity and improved work role function. The lower levels of pain post-intervention were related to greater work role function.

Evanoff et al. (1999) studied the effect of a PE team on rates of injury, lost time and MSDs among hospital orderlies. They also hypothesized that direct worker participation in problem-solving would improve job satisfaction. The PE team received training in team building, risk identification and control, and undertook supervised exercises in observation and measurement. The PE team was responsible for identifying and prioritizing safety problems and implementing solutions. The primary safety intervention implemented was the development of standardized lifting techniques. All of the orderlies received training on the standardized procedures according to a lifting manual written by the team. New employees were required to complete the training before being allowed to work independently. The rates of injuries and lost days decreased following the two-year intervention. At the 15-month follow-up, there were significant reductions in the proportion of employees who reported MSDs. Statistically significant improvements were
observed in job satisfaction, perceived job stressors and social support among the orderlies. However, based on the presented results, it is not clear whether there were any significant differences between the intervention and control group.

**Randomized controlled trials**

The aim of the CRT conducted by Tsutsumi et al. (2009) was to study the effect of a participatory intervention for workplace improvement on mental health and job performance among blue collar workers manufacturing electronic equipment. The intervention process lasted approximately 15 months. The intervention consisted of a half-day training workshop for facilitators of participative actions at their workplaces. The facilitators received information on mental health and the participatory approach for stress prevention. Supervisors were educated on the significance of positive mental health and improvement in the work environment, and given examples of good practices. The supervisors were trained to identify occupational stressors and to make suggestions for ways to reduce conflicts and to eliminate the sources of stress. In a workshop, the intervention group workers were provided with an introduction to the methodology for improving the work environment, and a lecture on hazard identification. They had group discussions on work improvements and presentations of action plans. During the 5-month implementation phase, two follow-up workshops were arranged. Mental health remained at the same level in the intervention group, but deteriorated in the control group. Job performance increased statistically significantly in the intervention group compared to the control group. However, after imputation of missing values, no statistically significant differences between the groups were observed.

The effect of a one-year PE program on MSDs and individual coping, job demands, job control and social support was studied in a CRT among operators in the aluminium industry (Morken et al. 2002). Three intervention groups, 'shift group with supervisor', 'shift group without supervisor', and 'managers only', were formed. The PE program consisted of 10 didactic sessions (1h 15 min) and discussion (45 min) chaired by a physiotherapist acquainted with occupational health services in the aluminum plants. Each session had a different topic related to physical, psychosocial, work-organizational, and individual risk factors of MSDs, basics of ergonomics, and coping with MSDs. Active participation of the group members responsible for identifying, prioritizing and
implementing solutions was emphasized. The implemented changes focused on redesign of workplace, working aids or tools, reducing repetitive-motion stress points and modifying the work processes to promote job variation. No significant changes on MSDs were found. Operators in the 'shift group without a supervisor' used coping strategies more often and social support improved slightly. Job demands and control did not differ between the groups.

Two individually randomized trials were targeted at the ergonomics of office work involving VDU. Ketola et al. (2002) evaluated the effect of an intensive ergonomics approach and education. In the intensive ergonomics group, two physiotherapists visited each worker and introduced an ergonomic checklist for VDU work. The workers assessed independently their workstations with the aid of the list. Potential improvements based on the workers own views and the physiotherapist's observations were discussed. The workers were encouraged to participate actively in the redesign in their workstations. Advice to take care of their work postures and to add short pauses into work was given. In the education group, in the 1-hour training session, the workers were instructed on the principles of VDU work, they received the same checklist, and were encouraged to evaluate their own workstation and implement the changes. The same advice considering work postures and pauses during the work was given. The control group received only a one-page leaflet. The intensive ergonomics and ergonomic education groups showed less musculoskeletal discomfort than the control group after a two-month follow-up. No significant differences in the strain level or in pain or any long-term effects on discomfort, strain, or pain were found at the 10-month follow-up.

In Bohrs' study (2000), the control group had no education session. The traditional group had a 1-hour education session consisting of a lecture and informational handouts about office ergonomics. The participatory education group received a 2-hour education session with similar content but incorporating discussion, problem-solving exercises, and evaluation and modification of work areas according to the information received. In follow-ups at three, six and 12-months, those who received education reported less pain/discomfort or psychosocial stress than those in the control group, but there was no indication that the differences were related to better work area configuration or improved worker postures. The workers in the participatory group reported a better health status than
those in the control or the traditional education group. Later Bohr (2002) reported that there was no evidence that the PE method was more effective than the traditional method in encouraging the workers to optimize the positions of their work equipment or to maintain good working postures.

A large CRT ('Stay@Work') aimed to investigate the effectiveness of a PE to prevent LBP and neck pain among blue and white collar workers is underway in the Netherlands (Driessen et al. 2008). The intervention group is participating in a six-step PE programme. A working group was created including eight workers, a representative of the management, and an occupational and health and safety coordinator. During a one-day meeting, the working group followed the steps of the PE program and identified the most important risk factors, the most fundamental ergonomic measures on the basis of group consensus, and prepared the implementation plan. If needed, a second meeting could be arranged to evaluate the status of the implementation phase. The results are expected in 2010.

In summary, there is little evidence for the effectiveness of preventive ergonomics interventions. The physical and organizational ergonomics interventions do not seem to be more effective than interventions including no ergonomics. However, the amount of high-quality studies is insufficient to allow any final conclusions to be drawn. Evidence of the effectiveness of PE is lacking since most studies suffer from methodological flaws and only a few RCTs exist.
Table 2. Effects of participatory ergonomics interventions on musculoskeletal disorders (MSDs) and psychosocial factors at work

<table>
<thead>
<tr>
<th>First author</th>
<th>Study design</th>
<th>Participants</th>
<th>Follow-up</th>
<th>Intervention/ Aim</th>
<th>Effects on MSDs/ psychosocial factors at work</th>
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<td>Total</td>
<td>Intervention</td>
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<td>Non-randomized controlled trials</td>
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<tr>
<td>*Kobayashi, 2008; Japan, manufacturing enterprise</td>
<td>Before-after with control group</td>
<td>1434 workers from 45 departments. Pre-post intervention matched questionnaire n=1071</td>
<td>n= 321 workers from 9 departments</td>
<td>Pre-post questionnaires administered 12 months apart</td>
<td>Effects of a participatory organizational intervention on the reduction of job stressors and the enhancement of the mental health were studied</td>
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<td>n= 750 workers from 36 departments</td>
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<td>n= 321 workers from 9 departments</td>
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<td>n= 750 workers from 36 departments</td>
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<td>n= 1071</td>
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<td>12 months apart</td>
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<td>Sick leave data were obtained from the company registries</td>
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<tr>
<td>*Laing, 2005, 2007; Canada, an multinational automotive parts manufacturing company</td>
<td>Before-after with control group</td>
<td>The complete pre-post matched questionnaire n = 83</td>
<td>n = 44</td>
<td>Pre-post questionnaires administered 10 months apart</td>
<td>Effectiveness of a PE intervention 1) in reducing worker pain severity through changes aimed at reducing physical</td>
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Effect sizes: not given

- Among women, skill underutilization (p=0.048), supervisor (p=0.000) and co-worker support (p=0.036), psychological distress (vigor p=0.026, depression p= 0.010), job satisfaction (0.043), and health risks (HR associated with job stressors (total HR p=0.000, HR associated with job strain p= 0.030, and HR associated with worksite support p=0.000) changed significantly in the intervention group.

- Improvements in the outcomes were more prominent among departments with a 50% or higher participation rate in the planning workshops (p=0.000-0.030) and among departments with 50% or higher rate of implemented vs. planned actions (p=0.001-0.039).

**Effect sizes: not given**

- No favourable effect among men
- No effect on sick leave among either gender

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Table 2 (continued)

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<tr>
<th>First author</th>
<th>Study design</th>
<th>Participants</th>
<th>Follow-up</th>
<th>Intervention/Aim</th>
<th>Effects on MSDs/psychosocial factors at work</th>
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</thead>
<tbody>
<tr>
<td>*Rivilis, 2006; Canada, a courier company</td>
<td>Before-after with control group</td>
<td>The complete pre-post matched questionnaire n = 122</td>
<td>one depot n = 71</td>
<td>a nearby depot in the same region as a control group n = 51</td>
<td>Pre-post questionnaires administered 14 months apart. At baseline, intervention group workers were an average 5.2 years older (p= 0.0289) and experienced more pain (p=0.021) than control group. Evaluation of a PE intervention aimed at improving musculoskeletal health; A hypothesis that with greater process implementation intensity, greater change in exposure to MSD risk factors would be observed and result in improvements in health outcomes. Greater participation in the process was associated with increased levels of job influence (p= 0.006) and communication (p= 0.094). Improvements in communication levels were associated with reduced pain intensity (p= 0.008) and improved work role function (WRF, how much of time at work is limited by musculoskeletal pain, p=0.025). Lower levels of pain post-intervention were related to greater WRF (p= 0.050).</td>
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2) Communication dynamics regarding ergonomics was enhanced in the intervention group (p = 0.004-0.045 for all 5 questions). No differences between the groups were observed for the 2 questions on overall workplace communication dynamics (between labour and management and between one and his/her co-workers). Effect sizes: not given.

- No statistically significant differences in decision latitude or influence.
<table>
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<th>First author Year</th>
<th>Study design</th>
<th>Participants</th>
<th>Follow-up</th>
<th>Intervention/ Aim</th>
<th>Effects on MSDs/psychosocial factors at work</th>
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| *Evanoff, 1999; USA, hospital orderlies | Prospective intervention trial (before-during-after) | Mean employment during study period 100-110 orderlies, 67 orderlies pre-intervention and 88 post-intervention completed questionnaire, Other hospital workers used as a concurrent control | · 1 month · 7 months · 15 months · 24 months | · The aim was to study if the implementation of a PE team would result in lower rates of injury, lost time and musculoskeletal symptoms (mean body comfort rate, 1=uncomfortable, 5=comfortable) · It was hypothesized that direct worker participation in problem solving would improve job satisfaction (three summary scales; the Job Satisfaction Scale (3 items), the Work Apgar (social support, influence, 7 items), and the Psychosocial Stressors scale (3 items)) | · In the intervention group, decreased risks of work injury (RR =0.50, 95% CI 0.35-0.72), lost time injury (RR=0.26, 95% CI 0.14-0.48) and injury with 3 or more days of time loss (RR= 0.19, 95% CI 0.07-0.53). Total lost days declined from 136 to 23 annually per 100 full-time worker equivalents (FTE). · In the intervention group, mean discomfort rating changed from 3.5 to 3.9, p<0.05 neck; 3.0 to 3.4, p<0.01 lower back; 3.7 to 4.0 p<0.01 forearm; 3.3 to 3.8, p<0.05 knee. Based on the presented results, it is not clear whether there were statistically significant effects between the groups. · In the intervention group, improvements in job satisfaction (from 7.7 to 8.8, p<0.01), in work Apgar (from 14.6 to 15.8, p<0.05), and in perceived psychosocial
| | | | | | Measures/outcomes; perceived physical demands, work organizational risk factors (perceptions of job influence, communication dynamics), self-reported pain/discomfort and work function outcomes | Effect sizes: not given |
Table 2 (continued)

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<tr>
<th>First author</th>
<th>Year</th>
<th>Industry/sector</th>
<th>Study design</th>
<th>Participants</th>
<th>Follow-up</th>
<th>Intervention/ Aim</th>
<th>Effects on MSDs/psychosocial factors at work</th>
</tr>
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<tbody>
<tr>
<td>Driessen, 2008; The Netherlands, blue and white collar workers of four Dutch companies</td>
<td>A cluster-randomized controlled trial</td>
<td>6759 workers working at 36 departments were expected to participate at baseline. The departments consisting of about 150 workers were pre-stratified and randomized. Based on power analysis (ICC 0.73, power 0.80, α 0.05, 25% decrease between the compared groups) 1662 workers would be needed (About 24-36 departments with 831 workers / group). Expecting a drop-out rate of 20%, an initial sample of 2076 workers would be needed.</td>
<td>Total 5759 workers</td>
<td>Intervention: n= 1662 workers Control: n= 4137 workers</td>
<td>6 months</td>
<td>The study will investigate the (cost) effectiveness of PE to prevent LBP and neck pain</td>
<td>Results are expected in 2010. · Primary outcome: an episode of LBP and neck pain. · Secondary outcomes: actual use of ergonomic measures, physical workload, psychosocial workload, intensity of pain, general health status, sick leave and work productivity. · Cost-effectiveness analysis will be performed from the societal and company perspective.</td>
</tr>
<tr>
<td>*Tsutsumi, 2009; Japan, blue-collar workers manufacturing electronic equipment</td>
<td>A cluster-randomized controlled trial</td>
<td>n = 11 assembly lines n = 97 workers n = 6 lines n = 47 workers n = 5 lines n = 50 workers</td>
<td>Approximate-ly 12 months</td>
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<td>To explore the effect of a participatory intervention for workplace improvement on mental health and job performance. · General Health Questionnaire (GHQ) and Health and Work Performance Questionnaire (HPQ).</td>
<td>GHQ scores remained at the same level in the intervention group, but deteriorated in the control group. HPQ scores increased in the intervention group, but decreased in the control group (p = 0.048). After imputation of missing values, there was no statistically significant difference between the groups. · Effect size: not given</td>
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<th>First author Year Industry/sector</th>
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<tbody>
<tr>
<td>*Morken, 2002; Norway, aluminium industry</td>
<td>A cluster-randomized controlled trial</td>
<td>All workers from 8 plants completed the questionnaire. Baseline n=5654, follow-up n=5143, matched n=3321, n=95 groups n=2181 operators Workers from the production line were randomized</td>
<td>n= 40 groups, n= 414 operators</td>
<td>3 Intervention groups (I): I1) 'shift group with supervisor' (n=20 groups of operators &amp; supervisors, n=132 operators) I2) 'shift group without supervisors' (n=18 groups of operators only, n=135) I3) 'managers only', (n=2 groups of supervisors &amp; managers and 10 groups of operators n=147)</td>
<td>n = 55 groups n= 1767 operators</td>
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<td></td>
<td>Control group A (CA) n= 55 groups n= 423 operators</td>
<td>Control group B (CB) From other parts of the same plant, n=1344 operators, non randomized</td>
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<tr>
<td>First author Year Industry/sector</td>
<td>Study design</td>
<td>Participants</td>
<td>Follow-up</td>
<td>Intervention/ Aim</td>
<td>Effects on MSDs/psychosocial factors at work</td>
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<tr>
<td>Ketola, 2002; Finland, municipal office workers using video display units</td>
<td>A randomized controlled trial</td>
<td>n = 124</td>
<td>n= 39</td>
<td>- 2 months - 10 months</td>
<td>Evaluation of the effect of an intensive ergonomic approach and education on workstation changes and MSDs (discomfort, strain pain).</td>
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<td>- At 2 months follow-up, in the intensive vs. control group, significant (p=0.001-0.025) reduction in discomfort in the neck (mean 2.7 vs. 3.3), area between neck and shoulder (right side) (2.5 vs. 3.1), shoulders (2.2 vs. 2.8 right, 1.9 vs. 2.4 left), right forearm (2.1 vs. 2.5), left fingers (1.8 vs. 2.3), and upper back (2.2 vs. 2.9). In the education group, similar changes (p=0.002-0.009) except shoulders. At 10 months follow-up, no statistically significant changes were detected in both groups compared to control group in discomfort, strain or pain.</td>
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<tr>
<td>*Bohr, 2000; St. Louis Missouri, USA, reservation center/office (using mostly computer)</td>
<td>A randomized controlled trial</td>
<td>Subjects were selected at random from a list of volunteers who were employed as agents at the centralized reservation, used computers at least 5 h per work day n= 154 at baseline n=124 at the 12 months</td>
<td>n= 47</td>
<td>- 3 months - 6 months - 12 months</td>
<td>Investigation of the efficacy of worker education programs in preventing MSDs</td>
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<td>- Upper body score: control group reported higher frequency of pain/discomfort throughout the study than either intervention groups [F (2,151) = 4.86, p&lt;0.01] No statistically significant difference between traditional and participatory education group.</td>
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<td></td>
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<td>- Lower body score: no statistically significant difference across the groups.</td>
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</table>
2.5. Kitchen work as a target of an ergonomics intervention

The present study was targeted to kitchen work. Kitchen workers are mainly women and they suffer a high prevalence of MSDs (Huang et al. 1988; Ono et al. 1997; Ono et al. 1998; Perkiö-Mäkelä et al. 2006; Nagasu et al. 2007; Shiue et al. 2008). The work is physically demanding (Shibata et al. 1991; Ono et al. 1997; Ono et al. 1998) and it often involves ergonomic problems (Huang et al. 1988; Shibata et al. 1991). The HORECA sector (hotels, restaurants, catering) employs about eight million people in the European Union. In 2000, almost 55% of the EU-15 workers in the sector reported that their job involved painful or tiring positions compared to 45% across all sectors. The corresponding figures for carrying or moving heavy loads were 43% compared to 36%, and for repetitive hand or arm movements 64% compared to 56% overall. Pain in lower limbs is more common in the HORECA sector than elsewhere (European Agency for Safety and Health at Work 2008).

In a large Japanese cross-sectional survey among cooks (n= 5835) working in school lunch services, the prevalence of LBP and its associations with various risk factors were recently examined (Nagasu et al. 2007). About 83% of the workers were women (mean age 48 years). Female gender was associated with LBP [prevalence ratio, (PR) 1.3]. Several other factors were significantly associated with the prevalence of LBP. In women, these included no regular physical activity, the number of hours of sleep ≤ 7, and the number of prepared lunches per cook. In both genders, current and past smoking, lack of breaks in the morning session, physical kitchen environment (noisy surroundings, poor state of drainage, presence of slippery surfaces, bumps and obstacles on the floor), and the height of cooking equipment (e.g. counter-tables, kitchen sinks, cauldrons) were associated with LBP. In addition, job dissatisfaction, stress at work, financial constraints, health-related stress, and worries about the future were similarly associated. The PR values varied from 1.1 to 1.7, being strongest for stress at work (PR 1.7), and current (PR 1.6) and past (PR 1.4) smoking. The annual incidence of MSDs among Chinese restaurant cooks (n= 52 261) was observed to be higher (ORs 1.3-1.4) compared to the age and sex matched general population. There was a trend for increasing MSD incidence with age in both the cooks and the reference group (Shiue et al. 2008).
In one considers municipal occupations in Finland, then the kitchen workers are among the top five occupations with the highest sickness absence and disability pension rates (Forma 2004; Vahtera et al. 2008) as well as reporting high physical work load and fast work pace, unsatisfactory working climate, poor perceived health, low correspondence between knowhow and work, need for education, and fear of temporary dismissals or lay-offs (Forma 2004). In the planning phase of the present intervention study, kitchen workers were considered to represent good subjects for ergonomic improvements. Based on observations in kitchens during the development phase of the study, many generic risk factors for MSDs were observed. Awkward postures, repetitive and forceful movements, and manual material handling typically occurred often in the daily routine. The work imposed both static and dynamic load on the musculoskeletal system. The workers performed several parallel tasks, they worked under time pressure and high mental and physical workloads. In the study, seven main work tasks were distinguished: preparation (e.g. washing, paring, and cutting of the groceries), cooking and baking, distribution and serving of the food (e.g. dishing out and dosage of the food), dishwashing (e.g. sorting, pre-washing and washing of the dirty dishes/ sorting and setting of the clean dishes), cleaning and maintenance of room and equipment (e.g. cleaning tables and floors, handling and transit of refuses), and receiving and storing of raw material. Packing food into thermal transport cases was an extra task in kitchens which prepared the food to be transported to other kitchens where the food was delivered to the clients.

Little previous research had focused on this challenging occupational group. Kitchens were also the correct sized units suitable for a cluster randomized design. In particular, municipal kitchens were thought to be sustaining workplaces that would allow a long enough follow-up without an immediate threat to their continuing existence.
3. THEORETICAL FRAMEWORK OF THE STUDY

There are several theoretical models describing the multifactorial etiology of MSDs (Huang et al. 2002; Karsh 2006). These are needed to target interventions that might prevent or reduce MSDs. The theories also guide in the selection of variables that should be controlled for in a study. The theoretical basis of this thesis (Figure 1) is based on the ecological model of Sauter and Swanson (1996) that was also the framework of the entire ERGO-study. This model, originally designed for office and VDU work, incorporates biomechanical, psychosocial and cognitive factors, the last of these three components being the one distinguishing it from the other models. According to this model, MSDs are related to work technology that includes workplace characteristics, and the nature of work processes and tools. The work technology is linked directly to physical work demands, as defined by the physical connection between a tool and a worker, and to the work organization. The pathway from the work organization to the physical demands proposes that the physical demands of work are affected by organizational demands; for example, increased repetition may be caused by increased specialization of work tasks. A direct path is seen also between the work organization and psychosocial strain which can then affect the biomechanical strain. The model suggests that the relationships between biomechanical strain and the development of MSDs are mediated by complex cognitive processes that involve the detection and sensation of symptoms and their attribution to the musculoskeletal system. The work organization, psychological strain, and individual factors have an influence on the connection between biomechanical strain and MSDs, and on the manner by which workers detect and respond to physical sensations. Finally, the model shows the reciprocal links between MSDs and the work organization and psychological strain.

Study hypotheses based on the theoretical framework

It was hypothesized that by implementing ergonomics changes in tools, equipment and technology aimed at optimisation of biomechanical and mental load and affecting factors related to work organization, it would be possible to prevent MSDs and to improve the psychosocial work environment among kitchen workers (I-II). At baseline, before the intervention started, kitchen workers were assumed to have a high occurrence, not only of
single-site pain, but also of pain at multiple anatomical sites (III). In study IV, there were two hypotheses assuming opposite time sequences: that psychosocial factors at work and mental stress would predict the occurrence of MSP, and that MSP would predict the occurrence of psychosocial factors at work and mental stress.

Figure 1. Framework of the study based on the conceptual model of work-related musculoskeletal disorders, adapted from Sauter and Swanson 1996. Boxes with dash lines refer to the measures used in the current study.
4. AIMS OF THE STUDY

The primary aim was to study the efficacy of a workplace PE intervention in preventing MSDs among municipal kitchen workers. Second, the effects of the PE intervention on psychosocial working conditions as intermediate outcomes were studied. Furthermore, the occurrence of MSP and the associations between MSP and psychosocial factors at work over time were examined.

The specific aims were:

1. To study the efficacy of a PE intervention in preventing MSDs (I).
2. To investigate the effects of a PE intervention on psychosocial factors at work as intermediate outcomes of the intervention (II).
3. To examine the co-occurrence of musculoskeletal pain in seven distinct body sites and their combinations in female kitchen workers (III).
4. To identify the developmental patterns of MSP and of psychosocial factors at work during a two-year follow-up period. To study the interrelationships between psychosocial factors at work and MSP in female kitchen workers (IV).
5. MATERIALS AND METHODS

5.1. General description of the study

The sub-studies comprising this dissertation are part of a larger research programme carried out by the FIOH during the years 2002-2005 in collaboration with municipal kitchens in four large cities in Finland. The Academy of Finland (Health Promotion Research Programme), the Finnish Work Environment Fund, the Ministry of Labour, and the Local Government Pensions Institution financially supported the study. The Ethics Committee of the FIOH approved the study proposal.

At the beginning of the study, meetings were arranged in each city where the management and kitchen workers were informed about the project and encouraged to participate. First, meetings with representatives of foodservice management were held in order to obtain their approval and commitment. Next, information sessions for the workers were held. In these sessions, the aims of the study and the study protocol were described. A research agreement was signed with each city and a written informed consent was obtained from each kitchen and each worker who agreed to participate in the study.

Flow of the study

The flowchart of the study, with the eligibility criteria for participation, is presented in Figure 2. Altogether 122 kitchens (60% of those eligible) were randomized into intervention or control groups. Three kitchens dropped out immediately after the randomization and thus 119 kitchens of schools, nurseries, and nursing homes, with a total of 504 workers participated in the study. For feasibility reasons, the intervention (n= 59) and control (n= 60) kitchens were divided into 16 series each including eight kitchens (four intervention and four control kitchens) on average. The series entered the active study phase sequentially in time. Within each series, the kitchens of both study arms proceeded parallely. The first series started in the spring of 2002 and the last ones in the autumn of 2003. By the end of 2004, the intervention phase was completed. Each series had a 12-month post- intervention follow-up. The follow-up phase was completed by the end of 2005.
5.2. Study designs and subjects

Detailed descriptions of the study designs and study material analyzed in the various sub-studies are given in Figure 3.

One of the sub-studies was cross-sectional (III) and focused on the co-occurrence of pain in seven body sites at baseline. Here the subjects were composed of 523 workers from all the initial 122 kitchens. Only 19 of the workers were men, and therefore the analyses were restricted to women only (n=504).

Study I describes the effects of a PE intervention on MSDs and study II investigates the effects on psychosocial factors at work. The subjects at baseline were 504 workers in 119 kitchens. Cross-sectional open sample data were collected at nine time points. The number
of workers participating in different cross-sections, by study arm (59 intervention kitchens and 60 control kitchens), are seen in Figure 3.

In study IV, the intervention and control groups were pooled together in a two-year prospective study to investigate developmental patterns of MSP and to examine associations between MSP and psychosocial factors at work over time. The final study sample consisted of women with observed values of MSP in at least four time points of nine (n=385).

<table>
<thead>
<tr>
<th>Study III</th>
<th>Study I-II</th>
<th>Study IV</th>
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<tbody>
<tr>
<td>Cross-sectional</td>
<td>Cluster randomized trial</td>
<td>2-year longitudinal</td>
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<tr>
<td>122 kitchens</td>
<td>122 kitchens</td>
<td>119 kitchens</td>
</tr>
<tr>
<td>523 workers</td>
<td>3 kitchens dropped out</td>
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<tr>
<td>Women n = 504</td>
<td>119 kitchens participated</td>
<td>Intervention group n = 59</td>
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<tr>
<td>Men n = 19</td>
<td>Control group n = 60</td>
<td>Control group n = 60</td>
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<tr>
<td>Information on all 7 anatomical sites</td>
<td>No workers</td>
<td>Total</td>
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<td>n = 495</td>
<td>BL*</td>
<td>263</td>
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<td></td>
<td>I₁</td>
<td>241</td>
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<td>I₂</td>
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<td></td>
<td>I₃</td>
<td>105</td>
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<td>I₄</td>
<td>159</td>
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<tr>
<td></td>
<td>PIA*</td>
<td>232</td>
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<td>PI₃</td>
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<td>n = 504</td>
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<td></td>
<td>n = 487</td>
<td>17</td>
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<td></td>
<td>Excluded</td>
<td>Information</td>
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<td></td>
<td>≥ 4 time points</td>
<td>n = 385</td>
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</table>

Figure 3. Study designs and study materials in the original studies.

*BL; baseline, I; intervention phase, PI; post-intervention follow-up phase.† PIA, post-intervention assessment. Five series finished the intervention at 9 months (I₉, n = 157) and 11 series at 12 months (I₁₂). The PIA was thus made either at 9 or 12 months after the start of the implementation phase of the intervention (combined n = 452).

5.3. Sample size, randomization and blinding

Since the participants within any cluster are more likely to be similar with each other than with the participants in another cluster, and also to have more similar outcomes, a larger sample size is required in a CRT to obtain adequate statistical power compared to an
individually randomized trial. Due to the cluster randomized design, within and between cluster correlations were considered. Based on power calculations and assumptions [intraclass correlation (ICC) 0.50, average of three subjects per kitchen, power of 0.80 to detect a difference of 15% in rates between the groups with $\alpha$ 0.05], the number of kitchens needed was estimated as 80 per group. Although the final number of kitchens was smaller, the sample size was sufficient because the ICC in the calculations proved to have been overestimated. At baseline, the empirical ICCs for the musculoskeletal and psychosocial work factor outcomes, as well as for perceived physical workload were below 0.30. The ICCs of workers in the same city area varied from 0.0 to 0.06.

Randomization was based on stratification by area (city district) and type of kitchen (school, nursery, home for senior citizens, other institution), and an assignment algorithm (Alternate Ranks Design, ARD) (Bonate 2000). Kitchens in each stratum were ranked in a descending order by the number of staff. The largest kitchen was randomized first, and thereafter, the next two were systematically allocated in pairs to the other study arm and so on. Randomization was carried out by an individual not otherwise involved in the study during the field phase.

It is impossible to conduct a PE intervention in a blinded manner. However, during baseline data collection, neither workers participating in the study nor the researchers knew to which group the workers would be allocated since the randomization was done after the baseline data collection (Figure 2). The researchers had no access to the questionnaire data during the data collection, and data analysis was started only after the follow-up data collection was completed.

### 5.4. Data collection, worker turnover and loss to follow-up

Data were gathered from questionnaires which a researcher distributed to all participating kitchens in both study arms. The baseline information (BL) was collected before randomization and thereafter every three months during the intervention (I_{1}, I_{6}, I_{9}, I_{12}) and the 12-month post- intervention follow-up period (PI_{3}, PI_{6}, PI_{9}, PI_{12}). Due to summer holidays at schools, at least one questionnaire was omitted in each kitchen series. Five series finished the intervention at 9 months (I_{9}, n = 157) and 11 series at 12 months (I_{12}, n
The post-intervention assessment (PIA) was thus made at either 9 or 12 months after the start of the implementation phase (combined n = 452). The next questionnaire (PI3) was always three months after the PIA. Extensive questionnaire data were collected at the BL and after the intervention phase (PIA) and a shorter questionnaire was distributed every three months during the intervention and the 12-month post-intervention follow-up period.

Response rates in different surveys varied between 92% and 99%. The proportion of workers employed in the same kitchen throughout the intervention phase was 86% in the intervention group and 84% in the control group. The respective values for the 12-month follow-up were 70% and 71%.

5.5. The participatory ergonomics intervention

The framework of the intervention was based on a model developed at the FIOH (Leppänen 2001). The intervention process is described in Figure 4. Active group work was emphasized, and workers were regarded as actors identifying problems, planning and evaluating changes, and implementing them in collaboration with the management and technical staff. The researchers provided guidance and support, and facilitated the progress of the process. The intervention consisted of a 2-month pre-implementation and 9-12-month implementation phase promoted by eight workshops (28 hours in total). Thus the duration of the intervention was 11-14 months. In two cities, a local steering group was established for improving the exchange of information between the research group and food service management.

The field study was carried out by four teams of two researchers trained in ergonomics and in good practice in kitchen work. One researcher (ergonomist) was responsible for supporting the intervention process. The main task of the other researcher was to assess the state of the ergonomics, to document the implemented changes and to distribute the questionnaires. Regular meetings were held to ascertain the similarity of working methods between the research teams. The project coordinator supervised the workshops and provided feedback to the researchers.
The foodservice managers and technical staff were invited to participate in the workshops. The kitchens were not provided with extra funding in association with the CRT and the ergonomics changes were implemented within their annual budgets. The municipal authorities agreed to prioritize the intervention kitchens in case of special needs arising during the intervention phase.

The control kitchens continued their normal activity. During 3-monthly visits, the researchers distributed questionnaires and collected information of all spontaneously implemented ergonomics changes and undertook short interviews. There were no other contacts with the researchers in these kitchens.

**Pre-implementation phase**
In the 2-month pre-implementation phase, all staff of the intervention kitchens were gathered together for two 5-hour workshops. In the first session, the workers were taught the basics of ergonomics and guided to analyze their work tasks and processes with the intention of identifying strenuous tasks and risk factors of MSDs. The kitchen staff had one month's time to continue the work analysis in their own kitchens and develop ideas to decrease their physical and mental workload. The ergonomist visited each kitchen once and gave them one supportive phone call. In the second workshop, each kitchen decided on their primary targets and planned how these would be best implemented.

**Implementation phase**
During the 9-12 month implementation phase, all staff of the intervention kitchens convened six times for a 3-hour workshop. Each workshop included a specific theme related to ergonomics and the progress of the intervention in each kitchen was thoroughly discussed. The ergonomist visited the kitchens if requested and provided support to the process. The workshops rotated from one kitchen to another to give the workers an opportunity to learn from each other's solutions and practices. The personnel of each kitchen kept a detailed diary about the ergonomic changes made. Based on the diaries, the researchers carefully recorded all ergonomic changes and evaluated the significance of the changes with regard to the load on the musculoskeletal system or occupational safety. The changes were classified according to the work tasks and by target.
Unconnected organizational reforms

An organizational reform of foodservices occurred simultaneously with the intervention study in two of the participating cities. In one city, the planning and implementation of the reform were executed concurrently with the intervention and in one other city, the reform was planned during the intervention and the new organization started during the 12-month post-intervention follow-up. In the new model, the major change was that cooking was centralized to large production kitchens, from which meals were delivered to other kitchens to be distributed to the clients. In addition, discussions about the possible outsourcing of the foodservices or organizing them as a public utility were underway in the two cities. Altogether 31 intervention and 31 control kitchens were involved in these organizational reforms. In study II, that examined the effects of the ergonomics intervention on psychosocial factors at work, independent and joint effects of the intervention and organizational reforms were studied in a secondary analysis.
5.6. Measures

5.6.1. Musculoskeletal disorders and multiple-site musculoskeletal pain

Musculoskeletal outcomes were measured by modified questions from the validated Nordic Musculoskeletal Questionnaire (Kuorinka et al. 1987).

*Musculoskeletal pain, trouble caused by pain and sick leave due to any pain during the past 3 months*

The questionnaires contained the following question on musculoskeletal pain in the neck, shoulders, forearms/hands, low back, hips, knees and ankles/feet: "Have you had 'x' pain during the past 3 months (no/yes)?" Trouble and sick leave due to pain were asked separately for each of the seven anatomical sites by the questions: "Please, assess how much trouble 'x' pain has caused during the past 3 months (1 = 'not at all', 7 = 'very much'), and "Have you been on the sick leave due to 'x' pain during the past 3 months (no/yes)?"

*Localized fatigue after the working day during the past 7 days*

Musculoskeletal fatigue was asked by a question: "How much bodily fatigue you have felt after the working day during the past 7 days (1 = 'not at all', 6 = 'very much')."

*Multiple-site pain*

A sum index (0 = 'no pain', 7 = 'pain in seven sites') was calculated to describe the occurrence of pain in multiple body sites during the past 3 months. The sum dichotomized to 0-2 pain sites (no MSP) and ≥3 pain sites (MSP) was used as an outcome measure. A sensitivity analysis was conducted by using 4 ≥ pain sites as the cut-off point. To obtain a view of concurrent pain in the body, the occurrence of all combinations of the seven anatomical sites was examined. In addition, the sites were combined to three larger anatomical areas: the axial (neck and low back), the upper limbs (shoulders, forearms/hands), and lower limbs (hips, knees, ankles/feet).
5.6.2. Psychosocial factors at work and mental stress

Psychosocial factors at work were assessed using questions adapted from a validated questionnaire (Elo et al. 1992). All items had initially five categories that were dichotomized to represent the presence or absence of the outcome as shown below.

Mental stress during the past month. "Stress refers to a situation in which a person feels tense, restless, nervous or anxious, or is unable to sleep at night because his/her mind is troubled all the time. Have you felt like this during the past month?" (1= not at all, 2= only a little, 3= to some extent 4= rather much, 5= very much); dichotomized as no (1-3)/ yes (4-5).

Mental strenuousness of work. "Is your work mentally strenuous?" 1= not at all, 2= rather light, 3= somewhat strenuous, 4= rather strenuous, 5= very strenuous. Dichotomized as no (1-3)/ yes (4-5).

Hurry at work. "Do you have to hurry to get your work done?" (1= never, 2= rather seldom, 3= now and then, 4= rather often, 5= constantly); dichotomized as no (1-3)/ yes (4-5).

Job dissatisfaction. "How satisfied are you with your present work?" 1= very satisfied, 2= rather satisfied, 3= neither satisfied nor dissatisfied, 4= rather dissatisfied, 5= very dissatisfied. Dichotomized as no (1-3)/ yes (4-5).

Poor co-worker relationships. "How do workmates get along at your workplace?" (1= very well, 2= rather well, 3= neither well nor badly, 4= there are some problems, 5= badly); dichotomized as no (1-3)/ yes (4-5).

Low job control. "At work, can you influence matters concerning yourself?"

Low skill discretion. "Can you use your knowledge and skills in your work?"

Low supervisor support. "Does your supervisor provide support and help when needed"? These questions had similar classes (1= very much, 2= rather much, 3= to some extent, 4= very little, 5= not at all) and were dichotomized as no (1-3) / yes (4-5).
5.6.3. Perceived physical workload

The question regarding the perceived physical workload was constructed specifically for the kitchen work since no suitable published methods for the purpose were available. The perceived physical workload (1= 'not at all', 7= 'very strenuous') of seven different work tasks (preparation, cooking and baking, distribution and serving of food, packing food to be delivered to clients, dishwashing, cleaning and maintenance of room and equipment, receiving and storing of raw material) was inquired. The mean was used in the analyses. The use of seven categories was based on the previous findings suggesting that the minimum number of categories should be between five to seven. In addition, up to seven, the reliability of the measure increases, but thereafter addition of more categories causes a decline in the reliability (Streiner and Norman 1995).

5.6.4. Covariates

Job title (foodservice manager, chef, cook, kitchen aid, other), years employed in kitchen work and employment (permanent, full-time) were characteristics of work history. Age, gender, height, weight, body mass index (BMI, kg/m²), overweight (no overweight; BMI < 25/ overweight; BMI ≥ 25 kg/m²), current regular smoking (no/yes), and physical exercise (≤ once a week/ > once a week) were other items included. The question regarding physical exercise was worded as follows: "During the past 12 months, how many times a week have you exercised at least 20 min per session, to the extent to cause perspiration?" (not at all, less than once a week, once a week, 2-3 times a week, 4-5 times a week, 6-7 times a week). A sum index of musculoskeletal pain (0 = 'no pain', 7 = 'pain in seven sites'), the mean of the perceived physical workload, organizational reforms (no/yes), study arm (intervention/control group), and city were also considered as covariates.

Type of kitchen (school, nursery, nursing home, geriatric service centre, other) was used as a cluster level characteristic.

The variables and their roles as outcomes, determinants or covariates, and statistical analyses in the original studies are summarized in Table 3.
<table>
<thead>
<tr>
<th>Study</th>
<th>Design and Subjects</th>
<th>Main outcomes</th>
<th>Intermediate outcomes/ Determinants</th>
<th>Covariates</th>
<th>Statistical analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Cluster randomized controlled trial 119 kitchens 504 workers</td>
<td>Musculoskeletal pain  Trouble caused by pain Sick leave due to any musculoskeletal pain Local musculoskeletal fatigue after workday during the past 7 days → seven anatomical sites: neck, shoulders, forearms/hands, low back, hips, knees, ankles/feet</td>
<td>Perceived physical workload Mental stress during the past month Mental strenuousness of work during the past 3 months Job satisfaction</td>
<td>Baseline level of the outcome Job satisfaction Age Gender Smoking Body mass index Physical exercise Permanent vs. fixed-term employment</td>
<td>Prevalence rates or mean scores of cross-sectional open population data The generalized estimating equations model, GEE</td>
</tr>
<tr>
<td>II</td>
<td>Cluster randomized controlled trial 119 kitchens 504 workers</td>
<td>Mental stress during the past month Mental strenuousness of work Hurry Job dissatisfaction Low job control Low skill discretion Poor co-worker relationships Low supervisor support</td>
<td></td>
<td>Baseline level of the outcome Age Musculoskeletal pain Perceived physical workload City</td>
<td>Prevalence rates of cross-sectional open population data The generalized estimating equations model, GEE</td>
</tr>
<tr>
<td>III</td>
<td>Cross-sectional 523 workers 19 men were excluded 504 women with information on all 7 anatomical sites n = 495</td>
<td>Musculoskeletal pain during the past 3 months in 7 anatomical sites; neck, shoulders, forearms/hands, low back, hips, knees, ankles/feet</td>
<td>Occupational title Age Work years</td>
<td></td>
<td>Prevalence rates Mann-Whitney U-test Cox proportional hazards regression</td>
</tr>
<tr>
<td>IV</td>
<td>Longitudinal 504 workers 17 men were excluded 487 women analysis among subjects with observations ≥ 4 time points/ 9 n = 385</td>
<td>Multiple-site musculoskeletal pain, ≥ 3 pain sites</td>
<td>Reciprocally Mental stress during the past month Hurry Low job control Low skill discretion Poor co-worker relationships Low supervisor support</td>
<td>Baseline level of the outcome Age Smoking Body mass index Physical exercise Perceived physical workload Organizational reforms Study arm</td>
<td>Semiparametric group-based method (trajectory analysis) Logistic regression models Time-lagged generalized estimating equations model, GEE</td>
</tr>
</tbody>
</table>
5.7. Statistical analyses

Summary of statistical analyses used in the original studies are presented in table 3. All analyses were performed using the SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) and SPSS version 12.0.1 (SPSS Inc., Chicago, IL, USA).

5.7.1. Effects of the participatory ergonomics intervention on musculoskeletal disorders and psychosocial factors at work

In studies I and II, the data were analyzed according to the intention-to-treat principle and the results were based on prevalence rates or mean scores of cross-sectional data of an open sample (Ukoumunne and Thompson 2001; Atienza and King 2002). In analyses by generalized estimating equations (GEE), the clustering of the data (workers, kitchens) was taken into account.

Assessment of the effects of the intervention was based on the comparison of the musculoskeletal outcomes between the groups (study arms) at each cross-section. The effects of covariates (Table 3) on the results were tested at the PIA and at the 12-month post-intervention follow-up (PI12). Effects on musculoskeletal fatigue and trouble due to pain were studied using mixed regression models, in which the kitchen series and individual kitchens were interpreted as random variables and the study arm, city, and potential covariates as fixed variables. In logistic regression models, which were used to analyze the effects on pain and sick leaves, the series and individual kitchens were used as subject effects. The repeated measures design was used in the re-analyses among the subgroup of subjects that remained in employed in the same kitchens throughout the study (cohort analysis, n = 307).

Between-group differences in psychosocial factors at work were studied at BL, at PIA and at PI12. The variable assessing the independent and joint effects of the intervention and the unconnected organizational reforms on psychosocial factors at work was coded as follows: 1=no intervention, no organizational reform; 2= intervention, no organizational reform; 3= no intervention, organizational reform; 4=intervention, organizational reform. No
intervention/ no organizational reform (1) was used as the reference group. Logistic regression models were first adjusted only for the baseline level of the outcome variable, and the second models also for other covariates (Table 8 and 9).

In all the models, ORs with their 95% confidence intervals (CI) were estimated as the measure of effect. Two-sided tests of statistical significance (p < 0.05) were used.

5.7.2. Multiple-site musculoskeletal pain and reciprocal associations with psychosocial factors at work

The occurrence of MSP at baseline was described in the cross-sectional study (III) among female workers, who had information on all seven assessed anatomical sites (n= 495, Figure 3). Differences in pain prevalence between age groups were assessed with the Mann-Whitney U-test. PRs for pain in one anatomical site relative to another were calculated using Cox proportional hazards regression. Adjustment was made for occupational title, age, and work years.

In study IV, the intervention and control groups were pooled to be analyzed prospectively over two-years (Figure 3). Since the number of men was so low, the analyses were carried out among women only. The aim was to study associations of psychosocial factors at work and mental stress with development of MSP over time, as well as associations in the reversed time order. To assess the average time trends of the prevalence of MSP, a mixed-effects logistic regression model was fitted to the data with linear time effects.

Associations between MSP and psychosocial factors at work were first studied by a time-lagged generalized estimation equations model (Liang and Zeger 1986). Repeated measurements of psychosocial factors were studied in relation to MSP three months later, and vice versa. Second, a semi-parametric group-based approach (trajectory analysis) (Nagin 1999; 2005; Jones and Nagin 2007) was used to identify developmental patterns of MSP and psychosocial factors at work. This method identifies groups (trajectories) of individuals who tend to have a similar profile over time. The Bayesian information criterion (BIC) is used as the basis for selecting the optimal model, number of trajectories, and their shape (intercept, linear trend, cubic or quadratic). Individuals are assigned to the
trajectory to which they have the highest probability of belonging. Ideally, the posterior membership probability should be near 1. To minimize the risk of misclassification, a model that includes trajectories with mean posterior assignment probabilities below 0.70 is not recommended (Nagin 2005). Measurements should be available in at least 50% of the assessed time points to reliably assess group membership probabilities, and in at least three time points to detect trajectories of quadratic shape (Kokko 2004). Based on these requirements, women with observed values of MSP in at least four time points of nine during the two-year follow-up constituted the final data set (n=385, Figure 3). After definition of the trajectories, associations of the baseline psychosocial factors at work with MSP trajectories were analyzed and vice versa. Finally, psychosocial work factor trajectories were studied in relation to MSP trajectories.

Logistic regression models with odds ratios (OR) and 95% confidence intervals (CI) were used to assess the associations. All models were adjusted for age, BMI, smoking, physical exercise, and perceived physical workload at baseline, and for the study arm (intervention/control) and organizational reforms (no/yes). In the reciprocal time-lagged analyses, the baseline value of the outcome was included among the independent variables.

6. RESULTS

6.1. Effects of the participatory ergonomics intervention in the prevention of musculoskeletal disorders (I)

6.1.1. Baseline characteristics

At baseline, there were no statistically significant differences in the 3-month prevalence rates of pain between the intervention and the control group. In both groups, pain was most common in the neck, low back, and forearms/hands, followed by pain in the shoulders, ankles/feet, knees and hips. No significant differences between the groups in the occurrence of MSP, sick leaves, or adverse psychosocial working conditions were observed. Compared to the control group, somewhat fewer permanent workers and more
smokers were assigned to the intervention group. Overall, randomization seemed to be successful and the comparability between the groups was good (Table 4).

Table 4. Baseline information given at the cluster and individual levels

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>Intervention group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cluster level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of kitchens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of kitchens (No.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>43</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Nursery</td>
<td>10</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Nursing home or geriatric service centre</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Individual level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of workers</td>
<td>263</td>
<td>241</td>
<td></td>
</tr>
<tr>
<td>Occupational title (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foodservice manager</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Chef</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Cook</td>
<td>20</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Kitchen aid</td>
<td>59</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.8</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Employed in kitchen work (years), range (median)</td>
<td>0-40 (17)</td>
<td>0-43 (20)</td>
<td></td>
</tr>
<tr>
<td>Employment (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permanent</td>
<td>81</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>95</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Women (%)</td>
<td>96</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Age (years), range (median)</td>
<td>19-63 (46)</td>
<td>19-62 (47)</td>
<td></td>
</tr>
<tr>
<td>Height (cm), range (median)</td>
<td>141-196 (165)</td>
<td>148-186 (165)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg), range (median)</td>
<td>49-147 (69)</td>
<td>46-132 (67)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²), range (median)</td>
<td>18-51 (24.9)</td>
<td>16-46 (24.6)</td>
<td></td>
</tr>
<tr>
<td>Smokers (%)</td>
<td>29</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Physical exercise (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ Once a week</td>
<td>37</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>≥ 4 times/week</td>
<td>21</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Any musculoskeletal pain during the past 3 months (%)</td>
<td>86</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Multiple-site musculoskeletal pain (≥ 3 pain sites) (%)</td>
<td>53</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Sick leave due to any musculoskeletal pain during the past 3 months (%)</td>
<td>15</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Perceived physical workload, mean (standard deviation)</td>
<td>3.7 (1.1)</td>
<td>3.7 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Mental stress during the past month (%)</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mental strenuousness of work (%)</td>
<td>15</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Hurry (%)</td>
<td>34</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Job dissatisfaction (%)</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Low job control (%)</td>
<td>15</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Low skill discretion (%)</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Poor co-worker relationships (%)</td>
<td>11</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Low supervisor support (%)</td>
<td>11</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>
6.1.2. Changes in ergonomics

Participation rates in the workshops during the intervention were excellent, on average 73%. Altogether 402 ergonomics changes, evaluated by the researchers as being beneficial with regard to load on the musculoskeletal system or occupational safety, were implemented in the intervention group during the intervention phase. In the control group, 80 changes were implemented spontaneously within normal activity during the same period. In the intervention group, over 100 of the intended changes were not completed (Table 5). Both in the intervention and control group, the changes mostly concerned the ergonomics of dishwashing, cooking and baking, and the distribution and serving of food. In the intervention group, the largest proportion of changes was targeted at work organization and methods (41%), whereas machines, equipment, and tools received the most attention (52%) in the control group (Table 6).

Examples of implemented changes and of good practices in kitchen work have been collected to the web pages of the FIOH and they are freely accessible (www.ttl.fi/keittiovinkit). Pehkonen et al. (2009a) have described some of the implemented changes in the context of the description of a video-based observation method aimed to assess musculoskeletal load in kitchen work.

Table 5. Number of implemented changes during the intervention and the 12-month post-intervention follow-up in the intervention and control group, and uncompleted changes in the intervention group. The number of changes per kitchen is given in brackets.

<table>
<thead>
<tr>
<th></th>
<th>Intervention group (n=59)</th>
<th>Control group (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>During intervention phase</td>
<td>402 (6.8)</td>
<td>80 (1.3)</td>
</tr>
<tr>
<td>During follow-up phase</td>
<td>101 (1.7)</td>
<td>69 (1.2)</td>
</tr>
<tr>
<td>Uncompleted</td>
<td>113 (1.9)</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 6. Distribution of implemented changes in the intervention and control group (402 vs. 80) subdivided according to work tasks and targets

<table>
<thead>
<tr>
<th>Work task (%</th>
<th>Intervention group (n=59)</th>
<th>Control group (n= 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Cooking and baking</td>
<td>18</td>
<td>39</td>
</tr>
<tr>
<td>Distribution and serving of food</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Packing food to be delivered for clients</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Dishwashing</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Cleaning and maintenance of room and equipment</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Receiving and storing of raw material</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Office work</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Target (%):**

<table>
<thead>
<tr>
<th>Target</th>
<th>Intervention group (n=59)</th>
<th>Control group (n= 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machines, equipment, tools</td>
<td>27</td>
<td>52</td>
</tr>
<tr>
<td>Layout, furniture</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Work organization, methods and practices</td>
<td>41</td>
<td>16</td>
</tr>
<tr>
<td>Materials†</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Physical work environment, safety‡</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

*E.g. removal of doorsteps. †E.g. new package sizes. ‡E.g. removing objects causing risk of injury.

### 6.1.3. Effects on health outcomes

No systematic differences in any health outcome were observed between the intervention and control group during the intervention or during the 12-month post-intervention follow-up. Prevalence rates of musculoskeletal pain and sick leave during the past 3 months were similar in the intervention and control groups (Figure 5). A few statistically significant differences were found in the cross-sections, but mainly to a non-hypothesized direction. Furthermore, no differences in MSP (≥ 3 pain sites) were found between the groups. During the study period, the 3-month prevalence of MSP varied between 51% and 61% in the intervention group, and between 47% and 59% in the control group (Figure 6).
Table 3. Musculoskeletal pain in seven anatomical sites and sick leave due to any pain during the past 3 months. Prevalence rates at baseline (BL), and every 3 months during the intervention (I) and the 12-month post-intervention (PI) follow-up. Comparison of the intervention and control group.

* p < 0.05. †Some of the kitchens finished the intervention at 9 months (I9) and some at 12 (I12) months. Thus, the PIA, post-intervention assessment was a combination of these assessments.

Figure 5. Musculoskeletal pain in seven anatomical sites and sick leave due to any pain during the past 3 months. Prevalence rates at baseline (BL), and every 3 months during the intervention (I) and the 12-month post-intervention (PI) follow-up. Comparison of the intervention and control group.

* p < 0.05. †Some of the kitchens finished the intervention at 9 months (I9) and some at 12 (I12) months. Thus, the PIA, post-intervention assessment was a combination of these assessments.
Figure 6. Multiple-site musculoskeletal pain (≥3 pain sites) during the past 3 months. Prevalence rates at baseline (BL), and every 3 months during the intervention (I) and the 12-month post-intervention (PI) follow-up. Comparison of the intervention and control group.
*p < 0.05. †Some of the kitchens finished the intervention at 9 months (I9) and some at 12 (I12) months. Thus, the PIA, post-intervention assessment was a combination of these assessments.

The mean scores of trouble caused by pain during the past 3 months and local musculoskeletal fatigue after a working day during the past 7 days displayed no significant differences between the intervention and control group at any time point (Figure 7).

Figure 7. Mean values of trouble caused by any musculoskeletal pain during the past 3 months and local musculoskeletal fatigue after a working day during the past 7 days. Minimum, 25 percentile, median, arithmetic mean (+), 75 percentile, and maximum. A comparison between the intervention and control group.
†Some of the kitchens finished the intervention at 9 months (I9) and some at 12 (I12) months. Thus, the PIA, post-intervention assessment was a combination of these assessments.
Inclusion of the baseline covariates in the analyses did not change the results. The results were similar among those who remained in the same kitchen throughout the study (cohort analysis, n=307). Similarly, no differences between age groups (≤ 45 years vs. > 45 years) in the effects of the intervention were observed. The effects of the intervention on health outcomes were similar in the intervention and control groups in the cities where there were organizational reforms and in the cities where no reforms took place (unpublished results).

6.1.4. Effects on perceived physical workload

Perceived physical workload showed no effect caused by the intervention. Overall mean values for the intervention group were 3.7 [standard deviation (SD) 1.1] at baseline, 3.8 (1.0) at the end of the intervention, and 3.9 (1.2) at the 12-month post-intervention follow-up. The respective figures for the control group were 3.7 (1.1), 3.8 (1.0), and 3.7 (1.2). When subdivided according to work tasks, no significant differences between the groups were observed (see the original publication I, Table 3).

6.2. Effects of the participatory ergonomics intervention on psychosocial factors at work (II)

No favourable effects of the intervention on psychosocial factors at work were found. Instead, a deterioration in several measures was observed. The adverse effects were mainly due to a joint effect of the intervention and unconnected major organizational reforms of foodservices in two of the participating cities.

Effects on psychosocial factors at work

Crude prevalence rates for each psychosocial factor at work at different time-points are presented in Figure 8 and the effects of the intervention on psychosocial factors at work in Table 7. At PIA, after adjustment for the baseline level of the outcome, workers in the intervention group were more dissatisfied with their work (OR 3.0, 95% CI 1.1-8.5), they reported more mental stress (2.3, 1.2-4.7) and felt co-worker relationships to be poorer (2.3, 1.0-5.2) compared to the workers in the control group. The effect on job dissatisfaction persisted at PI12 (3.0, 1.2-7.8). In the fully adjusted model, poor co-worker
relationships and job dissatisfaction at PIA remained statistically significantly poorer in the intervention group (see the original publication II, Table 3).

Figure 8. Crude prevalence rates of psychosocial factors at work according to organizational reform (Org -, no organizational reform; Org +, organizational reform). The rates are based on cross-sectional data of an open sample. Comparison between the intervention and control group at baseline (BL), at the end of the intervention (post-intervention assessment, PIA), and at the 12-month post-intervention follow-up (PI12).

*Some of the kitchens finished the intervention at 9 months and some at 12 months. Thus, the PIA was a combination of these assessments.
Table 7. Effects of the intervention on psychosocial factors at work. Odds ratios (OR) and 95% confidence intervals (CI) at the end of the intervention (post-intervention assessment, PIA), and at the 12-month post-intervention follow-up (PI12) for intervention group compared to control group

<table>
<thead>
<tr>
<th>Outcome</th>
<th>PIA (OR (95% CI)* (n = 448-449))</th>
<th>PI12 (OR (95% CI)* (n = 418-421))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental stress during the past month</td>
<td>2.31 (1.15 to 4.66)</td>
<td>1.22 (0.63 to 2.36)</td>
</tr>
<tr>
<td>Mental strenuousness of work</td>
<td>1.31 (0.74 to 2.36)</td>
<td>1.36 (0.75 to 2.46)</td>
</tr>
<tr>
<td>Hurry</td>
<td>0.85 (0.51 to 1.40)</td>
<td>1.21 (0.65 to 2.23)</td>
</tr>
<tr>
<td>Job dissatisfaction</td>
<td>3.02 (1.08 to 8.45)</td>
<td>3.03 (1.18 to 7.82)</td>
</tr>
<tr>
<td>Low job control</td>
<td>1.51 (0.84 to 2.69)</td>
<td>1.34 (0.74 to 2.41)</td>
</tr>
<tr>
<td>Low skill discretion</td>
<td>1.16 (0.54 to 2.49)</td>
<td>1.85 (0.88 to 3.88)</td>
</tr>
<tr>
<td>Poor co-worker relationships</td>
<td>2.29 (1.00 to 5.22)</td>
<td>2.03 (0.89 to 4.63)</td>
</tr>
<tr>
<td>Low supervisor support</td>
<td>0.99 (0.56 to 1.74)</td>
<td>1.77 (0.95 to 3.32)</td>
</tr>
</tbody>
</table>

*Adjusted for baseline level of the outcome.

**Joint effects of the intervention and organizational reforms**

No statistically significant independent effects of either the intervention or the organizational reforms were detected at PIA or PI12. Instead, Figure 8 illustrates that there was a joint effect between the intervention and the unconnected organizational reforms, in relation to the psychosocial factors. At PIA, even after adjustment for all covariates, mental stress was more common (OR above 3) among those with exposure to both the intervention and organizational reforms, compared to those who were exposed to neither (Table 8). Similarly, the mental strenuousness of work (OR over 2), job dissatisfaction (almost 12), low job control (almost 3), and poor co-worker relationships (almost 6) developed unfavourably in those workers subjected to double-exposure, i.e. both the intervention and the organizational reforms. At PI12, this kind of joint effect was found for mental strenuousness of work, hurry, low skill discretion, poor co-worker relationships, and low supervisor support.
Table 8. Joint effects of the intervention and organizational reforms on psychosocial factors at work. Those with no exposure to the intervention and no exposure to the organizational reforms as a reference group. Odds ratios (OR) and 95% confidence intervals (CI) based on cross-sectional analyses at the end of the intervention (PIA) and at the 12-month post-intervention follow-up (PI12). Neither the intervention nor the organizational reforms had any statistically significant independent effects on psychosocial factors at work at PIA or at PI12.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>PIA Model 1*</th>
<th>PIA Model 2†</th>
<th>PI12 Model 1*</th>
<th>PI12 Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td></td>
<td>(n = 448-449)</td>
<td>(n = 389-391)</td>
<td>(n = 418-421)</td>
<td>(n = 331-332)</td>
</tr>
<tr>
<td>Mental stress during the past month</td>
<td>3.45 (1.32 to 9.01)</td>
<td>3.46 (1.22 to 9.79)</td>
<td>2.24 (0.87 to 5.75)</td>
<td>1.96 (0.72 to 5.34)</td>
</tr>
<tr>
<td>Mental strenuousness of work</td>
<td>1.38 (0.63 to 3.00)</td>
<td>2.24 (1.02 to 4.89)</td>
<td>2.33 (0.98 to 5.54)</td>
<td>3.09 (1.20 to 7.94)</td>
</tr>
<tr>
<td>Hurry</td>
<td>1.01 (0.53 to 1.96)</td>
<td>1.17 (0.61 to 2.24)</td>
<td>2.23 (0.92 to 5.39)</td>
<td>2.52 (1.00 to 6.37)</td>
</tr>
<tr>
<td>Job dissatisfaction</td>
<td>11.0 (1.48 to 87.1)</td>
<td>11.6 (1.37 to 99.1)</td>
<td>5.10 (1.36 to 19.1)</td>
<td>†</td>
</tr>
<tr>
<td>Low job control</td>
<td>2.57 (1.07 to 6.13)</td>
<td>2.84 (1.03 to 7.84)</td>
<td>1.96 (0.90 to 4.25)</td>
<td>2.20 (0.99 to 4.89)</td>
</tr>
<tr>
<td>Low skill discretion</td>
<td>1.80 (0.60 to 5.38)</td>
<td>1.61 (0.49 to 5.25)</td>
<td>2.71 (0.93 to 7.93)</td>
<td>6.31 (1.34 to 29.6)</td>
</tr>
<tr>
<td>Poor co-worker relationships</td>
<td>3.34 (1.00 to 11.1)</td>
<td>5.71 (1.53 to 21.3)</td>
<td>3.75 (1.41 to 10.1)</td>
<td>2.88 (0.94 to 8.84)</td>
</tr>
<tr>
<td>Low supervisor support</td>
<td>0.81 (0.34 to 1.92)</td>
<td>1.43 (0.56 to 3.66)</td>
<td>2.51 (1.01 to 6.20)</td>
<td>3.18 (1.16 to 8.77)</td>
</tr>
</tbody>
</table>

* Adjusted for baseline level of the outcome. † Adjusted for baseline level of the outcome, age, musculoskeletal pain, and physical workload. ‡ Too few observations.

6.3. Occurrence of multiple-site musculoskeletal pain (III)

In studies III-IV, the study samples consisted of women only. At baseline, neck pain was the most common (3-month prevalence 71%), followed by pain in the low back (50%), forearms or hands (49%), shoulders (34%), ankles or feet (30%), knees (29%), and hips (19%). The occurrence of pain at multiple-sites concurrently was more common than single-site pain. Only 13% of the women reported no pain and 14% reported pain in only one site. Instead, about 73% reported pain in at least two, 36% in four or more, and 10% in six to seven sites. The symptoms occurred in 83 different combinations, in addition to those with no pain and pain in one site only. The PRs for pain in a single site relative to another varied from 1.3 to 5.8, e.g. neck pain was associated with pain in other sites with PRs varying from 1.3 to 1.6, and ankle or foot pain with ratios between 1.9 and 2.4 (Table 9). When assessed in three larger anatomical areas, i.e. the axial skeleton (neck and low back), upper limbs, and lower limbs, concurrent pain in all three areas was the most
common (36%) combination and this increased statistically significantly (p< 0.005) with age from 22% among the youngest group to 49% in the oldest group (Figure 9). The longer the women had been employed in kitchen work, the higher was the prevalence of pain in all three areas. There were no differences in the number of anatomical areas with pain between kitchen aids, cooks and other occupations.

Table 9. Prevalence ratios (PR) for pain in a single anatomical site relative to another site among women in kitchen work (n=495). Cox regression analysis

<table>
<thead>
<tr>
<th>Site</th>
<th>Neck*</th>
<th>Shoulder*</th>
<th>Forearm or hand*</th>
<th>Low back *</th>
<th>Hip*</th>
<th>Knee*</th>
<th>Ankle or foot*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain†</td>
<td>-</td>
<td>5.8†</td>
<td>3.2†</td>
<td>1.9†</td>
<td>3.1†</td>
<td>2.1†</td>
<td>2.4†</td>
</tr>
<tr>
<td>Shoulder pain†</td>
<td>1.6†</td>
<td>2.1†</td>
<td>1.4</td>
<td>2.1†</td>
<td>1.7†</td>
<td>2.0†</td>
<td></td>
</tr>
<tr>
<td>Forearm or hand pain†</td>
<td>1.6†</td>
<td>3.1†</td>
<td>-</td>
<td>1.6†</td>
<td>3.0†</td>
<td>1.5</td>
<td>2.0†</td>
</tr>
<tr>
<td>Low back pain†</td>
<td>1.4</td>
<td>1.5</td>
<td>1.6†</td>
<td>-</td>
<td>2.8†</td>
<td>1.8†</td>
<td>2.1†</td>
</tr>
<tr>
<td>Hip pain†</td>
<td>1.3</td>
<td>1.8†</td>
<td>1.7†</td>
<td>1.6†</td>
<td>-</td>
<td>1.6</td>
<td>1.9†</td>
</tr>
<tr>
<td>Knee pain†</td>
<td>1.3</td>
<td>1.6</td>
<td>1.3</td>
<td>1.5</td>
<td>1.8</td>
<td>-</td>
<td>2.1†</td>
</tr>
<tr>
<td>Ankle or foot pain†</td>
<td>1.3</td>
<td>1.9†</td>
<td>1.6†</td>
<td>1.6†</td>
<td>2.2†</td>
<td>2.1†</td>
<td>-</td>
</tr>
</tbody>
</table>

*Treated as the dependent variable. † Treated as the independent variable. ‡Prevalence ratios are statistically significant (p< 0.001), adjusted for 42 multiple tests.

Figure 9. Prevalence (%) of the number of painful anatomical areas (neck and low back, upper limbs, lower limbs) during the past three months among women in kitchen work (n=495) by age group. Areas classified as no, one, two, and three.
6.4. Reciprocal associations of multiple-site musculoskeletal pain with psychosocial factors at work (IV)

6.4.1. Time-lagged associations

Since no overall positive effects of the PE intervention on musculoskeletal symptoms (Figure 5) or on the occurrence of MSP (Figure 6) were found, the intervention and control groups were pooled so that they could be analyzed in the two-year longitudinal study.

All psychosocial factors at work, except low skill discretion and poor co-worker relationships, predicted the occurrence of MSP (defined as pain at ≥ 3 of seven sites) three months later, odds ratios varying from 1.4 to 2.1 after adjustment for all covariates (Table 10a). MSP predicted low job control, low supervisor support, and mental stress (ORs 1.4-2.0), respectively (Table 10b).

Table 10a. Psychosocial factors at work as determinants of multiple-site musculoskeletal pain (MSP, ≥ 3 pain sites) among female kitchen workers (n=385). In a time-lagged generalized estimating equation (GEE) model, psychosocial factors at work were assessed 3 months before MSP. Odds ratios (OR) and their 95% confidence intervals (CI)

<table>
<thead>
<tr>
<th></th>
<th>Multiple-site pain (OR (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low job control</td>
<td>1.8 (1.3-2.5)</td>
</tr>
<tr>
<td>Low skill discretion</td>
<td>1.4 (0.7-2.9)</td>
</tr>
<tr>
<td>Low supervisor support</td>
<td>2.1 (1.4-3.2)</td>
</tr>
<tr>
<td>Poor co-worker relationships</td>
<td>1.5 (0.8-2.6)</td>
</tr>
<tr>
<td>Hurry</td>
<td>1.4 (1.1-1.8)</td>
</tr>
<tr>
<td>Mental stress during the past month</td>
<td>1.6 (1.1-2.3)</td>
</tr>
</tbody>
</table>

*Adjusted for study arm, organizational reforms, and the following factors at baseline: age, body mass index, smoking, physical exercise, perceived physical workload, and MSP.
Table 10b. Multiple-site musculoskeletal pain (MSP, ≥ 3 pain sites) as a determinant of psychosocial factors at work among female kitchen workers (n=385). In a time-lagged generalized estimation equation (GEE) model, MSP was assessed 3 months before psychosocial factors at work. Odds ratios and their 95% confidence intervals

<table>
<thead>
<tr>
<th>Low job control</th>
<th>Low skill discretion</th>
<th>Low supervisor support</th>
<th>Poor co-worker relationships</th>
<th>Hurry</th>
<th>Mental stress during the past month</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP</td>
<td>1.4 (1.1-2.0)</td>
<td>1.3 (0.9-2.0)</td>
<td>2.0 (1.4-2.8)</td>
<td>1.4 (0.9-2.3)</td>
<td>0.8 (0.6-1.1)</td>
</tr>
</tbody>
</table>

*Adjusted for study arm, organizational reforms and the following factors at baseline: age, body mass index, smoking, physical exercise, perceived physical workload, and psychosocial factor at work.

6.4.2. Trajectories of multiple-site musculoskeletal pain and psychosocial factors at work

The 3-month prevalence of MSP varied from 50% to 61% during the two-year follow-up period. There was no statistically significant overall trend in the prevalence. In the trajectory analysis of MSP, the best fit was a four-group model including two trajectories with the intercept (no change over time) and two with a linear shape (Figure 10). The trajectory labelled as Low was composed of the workers whose prevalence of MSP was constantly low (n=129, 33%), and the High trajectory of those with a constantly high prevalence of MSP (n=146, 37%) over the two-year follow-up. The Descending trajectory consisted of 66 workers (19%) and followed a declining pattern. The Ascending trajectory was the smallest (n=44, 11%), and had a low initial prevalence of MSP that increased considerably toward the end of the follow-up. The mean trajectory-group assignment probabilities varied between 0.69-0.92, indicating that there was relatively little classification uncertainty. The results of a sensitivity analysis using ≥ 4 pain sites as the cut-off point for MSP were similar. The four-group model with the similar shapes of the trajectories had the best fit. The group sizes were 34% for Low, 28% for Descending, 13% for Ascending, and 25% for the High trajectory, and the group assignment probabilities varied from 0.77-0.91.
Figure 10. Multiple-site musculoskeletal pain trajectories (MSP, ≥ 3 pain sites) among female kitchen workers (n=385).
1 = Low (low prevalence of MSP), 2 = Descending (decrease in prevalence of MSP),
3 = Ascending (increase in prevalence of MSP), 4 = High (high prevalence of MSP).

Trajectories of psychosocial factors at work
The two-group model had the best fit for each of the psychosocial factors at work (Figure 11). Hurry had trajectories with the intercept shape with 23% of the workers belonging to the High trajectory. All other psychosocial variables had one trajectory with the intercept shape and the other with a linear ascending trend. The proportions of subjects belonging to the ascending trajectories were 23% (low job control), 7% (low skill discretion), 21% (low supervisor support), 10% (poor co-worker relationships), and 20% (mental stress). The mean assignment probabilities for all psychosocial work factor trajectories were over 0.70.
Figure 11. Trajectories of psychosocial factors at work and mental stress among female kitchen workers (n=385). Trajectories labelled as Low and Ascending (job control, skill discretion, supervisor support, co-worker relationships, and mental stress), or Low and High (hurry).

6.4.3. Associations of psychosocial factors at baseline with multiple-site musculoskeletal pain trajectories

After adjustment for covariates, poor co-worker relationships (OR 3.9, 95% CI 1.2-12.4), mental stress (3.1, 1.1-9.1) and hurry (2.1, 1.1-3.7) at baseline predicted belonging to the High vs. the Low MSP trajectory (Table 11; Baseline). None of the psychosocial work
factors at baseline predicted belonging to the Ascending vs. the Low or to the Descending vs. the High MSP trajectory.

6.4.4. Association of multiple-site musculoskeletal pain at baseline with psychosocial work factor trajectories

With the Low trajectory as the reference, MSP at baseline predicted belonging to the Ascending trajectory of low job control (OR 2.2, 1.3-3.9) and of mental stress (3.2, 1.7-6.0) (Table 12).

Table 11. Multiple-site musculoskeletal pain (MSP, ≥ 3 pain sites) trajectories in relation to psychosocial factors at work and mental stress among female kitchen workers (n=385). The psychosocial factors have been assessed at baseline and as trajectories (two groups, always contrasting Ascending/High vs. No). Comparison between the MSP trajectories as follows: Ascending vs. Low, High vs. Low, and Descending vs. High. Logistic regression analysis. Odds ratios (OR) and their 95% confidence intervals (CI)

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Contrast of multiple-site pain trajectories</th>
<th>OR (95% CI)</th>
<th>OR (95% CI)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low job control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>1.8 (0.5-6.2)</td>
<td></td>
<td>1.4 (0.6-3.4)</td>
</tr>
<tr>
<td>Trajectories, Ascending vs. No</td>
<td>High vs. Low †</td>
<td>2.0 (0.8-4.9)</td>
<td>5.0 (2.4-10.3)</td>
<td>0.3 (0.2-0.8)</td>
</tr>
<tr>
<td>Low skill discretion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>0.9 (0.1-9.7)</td>
<td></td>
<td>0.4 (0.0-3.5)</td>
</tr>
<tr>
<td>Trajectories, Ascending vs. No</td>
<td>High vs. Low †</td>
<td>1.1 (0.2-5.4)</td>
<td>3.1 (1.0-10.3)</td>
<td>0.1 (0.0-0.9)</td>
</tr>
<tr>
<td>Low supervisor support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>0.8 (0.2-2.8)</td>
<td></td>
<td>1.4 (0.6-3.3)</td>
</tr>
<tr>
<td>Trajectories, Ascending vs. No</td>
<td>High vs. Low †</td>
<td>1.3 (0.6-3.0)</td>
<td>2.3 (1.2-4.7)</td>
<td>1.1 (0.5-2.3)</td>
</tr>
<tr>
<td>Poor co-worker relationships</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>1.2 (0.2-7.4)</td>
<td></td>
<td>0.8 (0.3-2.2)</td>
</tr>
<tr>
<td>Trajectories, Ascending vs. No</td>
<td>High vs. Low †</td>
<td>3.9 (1.2-12.4)</td>
<td>3.5 (1.1-11.4)</td>
<td>1.0 (0.4-2.7)</td>
</tr>
<tr>
<td>Hurry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>1.2 (0.5-2.9)</td>
<td></td>
<td>1.0 (0.5-2.0)</td>
</tr>
<tr>
<td>Trajectories, High vs. No</td>
<td>High vs. Low †</td>
<td>2.1 (1.1-3.7)</td>
<td>1.7 (0.9-3.4)</td>
<td>0.9 (0.4-1.9)</td>
</tr>
<tr>
<td>Mental stress during the past month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, yes vs. no</td>
<td>Ascending vs. Low †</td>
<td>5.5 (1.6-19.0)</td>
<td></td>
<td>0.9 (0.3-2.4)</td>
</tr>
<tr>
<td>Trajectories, Ascending vs. No</td>
<td>High vs. Low †</td>
<td>3.1 (1.1-9.1)</td>
<td>8.6 (3.3-22.1)</td>
<td>0.6 (0.3-1.3)</td>
</tr>
</tbody>
</table>

† Development of psychosocial factors at work and mental stress over a two-year follow-up period.
‡ Number of subjects in multiple-site pain trajectories: Ascending (n= 44), Low (n=129), High (n=146), Descending (n=66).
§ Adjusted for study arm, organizational reforms and the following factors at baseline: age, body mass index, smoking, physical exercise, perceived physical workload.
¶ Adjusted for study arm and organizational reforms, and the following factors at baseline: age, smoking, physical exercise, perceived physical workload.
† No observations in 'BL yes' category in the Ascending trajectory of mental stress.
Table 12. Multiple-site musculoskeletal pain (MSP, ≥ 3 pain sites) at baseline as determinant of trajectories of psychosocial work factors and mental stress among female kitchen workers (n=385). Comparison between trajectories as follows: Ascending vs. Low* and High vs. Low†. Logistic regression analysis. Odds ratios (OR) and their 95% confidence intervals (CI)‡.

<table>
<thead>
<tr>
<th>Low job control*</th>
<th>Low skill discretion*</th>
<th>Low supervisor support*</th>
<th>Poor co-worker relationships*</th>
<th>Hurry‡</th>
<th>Mental stress during the past month*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP</td>
<td>2.2 (1.3-3.9)</td>
<td>2.5 (0.9-7.2)</td>
<td>1.5 (0.9-2.7)</td>
<td>1.8 (0.8-4.1)</td>
<td>1.5 (0.9-2.5) 3.2 (1.7-6.0)</td>
</tr>
</tbody>
</table>

‡Adjusted for study arm, organizational reforms, and the following factors at baseline: age, body mass index, smoking, physical exercise, perceived physical workload.

6.4.5. Psychosocial work factor trajectories in relation to multiple-site pain trajectories

Trajectories of psychosocial factors at work as determinants of MSP trajectories are presented in Table 11 (Trajectories). With the Low MSP trajectory as the reference, adverse changes in all psychosocial factors at work, except in low skill discretion and hurry, were associated with belonging to the Ascending MSP trajectory, with the odds ratios varying from 2.7 to 5.5 after adjustment for covariates. Similarly, adverse changes in all psychosocial factors, with the exception of hurry, were associated with belonging to the High MSP trajectory (ORs 2.3 to 8.6). With the High MSP trajectory as the reference, adverse changes in low job control and low skill discretion were inversely associated with belonging to the Descending MSP trajectory (ORs 0.1-0.3).

These associations were in many cases stronger than the effects of the baseline levels of the psychosocial factors on the MSP trajectories. Only poor co-worker relationships and hurry at baseline had higher risk estimates compared with their trajectories in predicting membership of the High vs. Low MSP trajectories. Hurry at baseline had also a slightly higher risk estimate compared with its trajectory in predicting membership of the Ascending vs. High MSP trajectory.
7. DISCUSSION

This study was intended to obtain evidence on the efficacy of PE in preventing MSDs, and to examine its effects on psychosocial working conditions. An intensive PE intervention of about one year's duration was conducted in municipal kitchens. The study was designed as a CRT. The co-occurrence of musculoskeletal pain in various body sites, and the association of MSP with psychosocial factors at work and mental stress were also evaluated.

7.1. Main findings and comparison to earlier studies

7.1.1. Effects of the participatory ergonomics intervention on musculoskeletal disorders and psychosocial factors at work in the CRT

It was hypothesized that optimization of physical and mental workload would have a preventive effect on the occurrence of MSDs and that active group work, and the direct participation of the workers in problem-solving, planning and implementing the ergonomic changes during the intervention would have a positive effect on the psychosocial work environment in the intervention kitchens. However, the obtained results did not support these hypotheses.

Although the intervention model proved feasible (Pehkonen et al. 2009c) and it was well received by both the workers and management, no effect of the intervention was found on musculoskeletal health. In some cross-sections, a few statistically significant differences in pain prevalence were seen, but mainly in an unanticipated direction. In the intervention group, the occurrence of pain seemed to be stable or even rising, and especially the number of pain-related sick leaves increased compared to the control group. No differences in trouble caused by pain or musculoskeletal fatigue were detected.

Perceived physical workload was not affected by the intervention. When the effects of the intervention on psychosocial factors at work were analyzed, a deterioration was observed in several of the workers' reports about psychosocial factors. At the end of the
intervention, the workers in the intervention group reported more mental stress, worse job dissatisfaction and poorer co-worker relationships compared to the workers in the control group. The effect on job dissatisfaction still persisted at the 12-month post-intervention follow-up. An adverse joint effect of the intervention and organizational reforms was seen for the majority of the eight measured psychosocial factors. Unfavourable effects on psychosocial factors at work may partly explain why the intervention did not have the expected impact on the occurrence of MSDs.

The variety in study designs, participants, outcome measures, and intervention programs complicate the comparison of our results to earlier findings. Since the CRT by the Dutch researchers (Driessen et al. 2008) is still underway and results are not yet available, the study by Morken et al. (2002) appears to be the only one with a similar study design. Their results were in line with the present findings. The study by Morken et al. (2002) aimed at examining the effects of a PE intervention on MSDs, psychosocial factors, and coping and included a large number of Norwegian aluminium industry workers. The intervention groups included only operators, only supervisors, and both. The authors found no effect of the intervention on MSDs, job demands, job control or social support, while coping skills increased, particularly in the operator group. Organizational restructuring took place during the intervention period. The authors collected information from the plants about restructuring, but did not report whether they had considered its effects in their analyses. They did not present sample size or power calculations or whether the clustering effect (plants, workers) was taken into account. However, the study population represented the whole aluminium industry sector and mostly consisted of men. The workers were from the production line, where the work is physically demanding, and the occurrence of MSDs among workers was high. The results of that study and the results of our study support and complement each other.

Two individually randomized trials on physically lighter sedentary work among VDU workers have been reported. Ketola et al. (2002) found a positive short-term effect of a PE intervention on musculoskeletal discomfort at their 2- month follow-up. However, pain or strain levels did not differ in the intervention groups compared to those in the control group, and no long-term effects on discomfort, pain or strain were observed at the 10-month follow-up. In the study of Bohr (2000), the intervention groups reported less upper
body pain/discomfort and work stress throughout the study period than the control group but no effects on lower body pain/discomfort were found. There was a higher turnover than expected particularly in the intervention groups. In a subsequent study, Bohr (2002) found no evidence that participatory methods would have been more effective than traditional methods in training in office ergonomics with regard to positioning work equipment correctly or to maintaining good working postures.

In a non-randomized trial involving manufacturing workers, Laing et al. (2005, 2007) had aims and results quite similar to those of the present study. They detected minor effects of PE on physical workload and no changes in perceived effort or pain severity levels. In the intervention group, communication dynamics regarding ergonomics were enhanced, but no differences between the groups were observed in overall communication between workers, co-workers and management.

This present study seems to be the first large CRT that has evaluated the efficacy of a PE intervention in reducing psychosocial load at work. Recently, Tsutsumi et al. (2009) examined the effect of a participatory workplace improvement intervention on mental health and job performance. The study was conducted in a company producing electrical devices. They randomized 11 assembly lines to an intervention (47 workers) and a control group (50 workers). Multilevel modelling was used to take into account that individuals were nested in units of assembly lines. Mental health and job performance improved in the intervention group compared to the control group. However, the overall effect was minor, the final sample sizes for the analyses were small, and after imputation of missing values, no significant effect was found. In addition, a non-randomized controlled trial by Kobayashi et al. (2008) was conducted in a manufacturing company. Nine of 45 departments participated in the intervention, and the remaining 36 departments served as the control group. Positive effects on mental health among women were found, but not among men.

One basic aim of the participatory approach is that the workers learn new skills during the process (Haines and Wilson 1998). Learning and internalizing of the principles of ergonomics gives the workers the capability to independently and continuously develop ergonomics in their daily work. In this present study, most of the changes in the
intervention group were targeted at work organization and methods (41%), whereas in the control group machines, equipment and tools received most attention (52%). After the end of the intervention, about 100 ergonomic changes had been implemented in the intervention group during the 12-month post-intervention follow-up period, indicating that the aim of learning was achieved.

Joint effects of the intervention and unconnected organizational reforms on psychosocial factors at work
The adverse overall effects of the PE intervention on psychosocial factors were accentuated in the kitchens with concomitant unconnected organizational foodservice reforms. No independent effects of either the intervention or the organizational reforms were detected. In some previous studies, interventions aimed at the redesign of work have had an adverse effect on psychosocial working conditions. A reorganisation of work at an automobile assembly plant resulted in a considerable decrease in the perception of opportunities to influence the work and in the degree of stimulation at work (Fredriksson et al. 2001). After the intervention, the prevalence of MSDs increased in the intervention group, but not in the control group from the same plant. High perceived workload and reduced occupational pride were associated with the increase in MSDs. Christmansson et al. (1999) observed that organizational redesign of manual repetitive assembly jobs mostly impaired the psychosocial work environment and increased the physical stress and risk of MSDs.

Unexpected organizational reforms have been shown to interfere negatively with interventions (Lagerström et al. 1998; Demure et al. 2000) and it is not uncommon that long-lasting intervention studies may be confronted by unforeseen changes beyond the control of the researchers (Cole et al. 2003; Silverstein and Clark 2004; Heaney and Fujishiro 2006). In this study, the centralizing of food preparation to certain kitchens during the organizational reforms increased the number of kitchens where food was only distributed to the clients. As a result, work tasks probably became more monotonous in the latter kitchens and diminished workers' possibilities to use their skills. The threat of outsourcing the functions or restructuring the foodservice as a public utility may have increased the employees' fear of redundancy causing uncertainty, extra tension and competition between the workers.
A participatory process can have negative effects on the psychosocial aspects at work if the process entails extra work (St-Vincent et al. 2006). In the present study, the participation in the intervention simultaneously with the implementation of the organizational reform may have been overly stressful to the workers. Participation in the workshops was more active in the cities with than in those without reforms, possibly increasing the overload of the workers in the midst of elevated work demands.

**Perceived physical workload**

No effect was found that the intervention would have altered perceived physical workload. The number of portions prepared per worker has been shown to be associated with MSDs (Shibata et al. 1991; Ono et al. 1997; Nagasu et al. 2007). According to the research diaries, in about one third of both the intervention and control kitchens, the number of portions increased during the study. A decrease in the number of personnel was recorded in four intervention and eleven control kitchens. This may have led to a higher intensification of work being done in the control kitchens.

Kitchen work is demanding, both physically and mentally. The employees work under pressure of time and perform various parallel tasks, many of which include exposure to a combination of risk factors of MSDs. For example, in long-lasting dishwashing, in receiving and storing of raw material, and cooking, the individual makes frequent bending and twisting of the trunk, lifting, repetitive movements of the hand, non-neutral wrist and shoulder postures, and there is need for forceful hand movements. The kitchen workers spend the working day almost exclusively walking or standing. Messing and Kilbom (2001) conducted a small workplace field study to assess the consequences of prolonged walking and standing among kitchen workers. They found that prolonged standing and short-distance slow walking caused a decrease in the plantar pain-pressure threshold over the workday. The majority of the workers had experienced foot pain during the previous 3 months. In the light of these results, it might be that standing or walking could be associated with lower limb pain. There is evidence that exposure to both dynamic and static repetitive motions, forceful exertion, and non-neutral body postures may cause MSDs in one or more anatomical sites (Punnett and Wegman 2004). The high occurrence of MSP found in this study could be connected with the pattern of loading in kitchen work. Workload may be rather uniformly distributed on the musculoskeletal system.
Reducing physical workload on musculoskeletal system is not straightforward. A reduction of biomechanical exposure on some body part may lead to an increased exposure on another and thus only transfer the site of the problem. It is difficult to quantify the exact levels of biomechanical exposure that are harmful to the musculoskeletal system. Thus, at best, one only knows that the level of exposure needs to be reduced, but not to what degree. Primary preventive interventions to reduce biomechanical exposure may encounter difficulties in demonstrating that a reduction in biomechanical exposure has resulted in a lower occurrence of MSDs. It has been proposed that a reduction of at least 14% in biomechanical exposure is required to achieve any detectable change in MSDs (Lötters and Burdof 2002; Burdorf 2010).

The results on physical risk factors based on objective expert assessment showed for some work tasks a reduction of the level of exposure (unpublished results). A subgroup analysis where the intervention and control groups were pooled showed that both the observed reduction in lifting and the perceived physical workload reduction in receiving and storing of raw material were associated with a lower risk of further shoulder symptoms during the 12-month follow-up (Pehkonen et al. 2009b). Yet, no overall effect of the intervention on perceived physical workload was detected. One explanation for this apparent discrepancy might be that the intervention did not produce a strong enough change on physical workload in the intervention group compared to the annually spontaneously implemented changes in the control group. It seems that the changes were not strong enough to influence the overall physical workload or the health outcomes. In some kitchens, acquisition of expensive new equipment and extensive structural changes would have been needed. Since no extra funding was available, most of the changes were low cost solutions.

7.1.2. The occurrence of multiple-site musculoskeletal pain

Since the number of men was low (4% in study III, 3% in study IV), the analyses concerning the occurrence of MSP and associations of MSP with psychosocial factors at work were conducted only in women. The cross-sectional study (III) described the overall prevalence of pain and specifically that at multiple sites concurrently at baseline, before the intervention started. Neck pain was the most common with seven of ten workers
reporting it, while every second worker reported forearm or hand pain and LBP. These estimates are higher than usually found in the normal female population of a comparable age range (Picavet and Schouten 2003; Bingefors and Isacson 2004; Kaila-Kangas 2007) and among the highest published in occupational samples (Blatter and Bongers 1999; National Research Council and Institute of Medicine 2001; Riihimäki 2005a). The one-month prevalence of LBP among Japanese female cooks working in school lunch services was recently reported to be 75% (Nagasu et al. 2007), that is even higher compared to the 3-month prevalence (50%) described here.

The finding of a high occurrence of MSP is in line with previous results among occupational samples and in the general population. The estimates for MSP among kitchen workers were even higher than those that have been presented in the general population or in occupational samples. About 73% of female kitchen workers reported pain in at least two sites. The respective figures among a representative sample of Finnish adults was 33% (Miranda et al. 2010), in the Dutch population 50%, and in Dutch women 39% (Picavet and Schouten 2003). Recently, Solidaki et al. (2010) evaluated MSP among Greek nurses, office workers and postal clerks. The study sample (n= 564) comprised predominantly of women, and 66% reported pain in two or more sites. In men doing manual lifting work, 63% had pain in at least two sites (Yeung et al. 2002). However, all comparisons are hampered by the sensitivity of pain prevalence estimates to differences in the way that the question was worded and different reference periods.

The seven pain locations did not cluster in any simple manner in our study material. Two thirds of the theoretically possible ($2^7=128$) combinations were empirically detected. When pain in three larger anatomical areas (neck and low back, upper limbs, lower limbs) was studied, every third woman (36%) reported pain in all three anatomical areas and every second of those aged 51-63 years, i.e. the co-occurrence of pain was age-related. It is possible that degenerative changes in the musculoskeletal system could contribute to phenomenon. According to the ACR criteria, classification of CWP includes pain in the upper and lower extremities (both sides of the body) and axial pain that must have been present for at least three months (Wolfe et al. 1990). Such a definition could not be applied here, as no information was available on pain persistence or on pain in the left and right lower limb separately. The observed amount of overlap in pain areas in this study is
clearly higher than the prevalence of CWP found in previous surveys. It has been estimated that approximately 10% of the general population report CWP and almost unanimously all studies have found higher rates among women compared with men, but the mechanism responsible for the skewed gender ratio remains unknown (Gran 2003).

In Finland, as well as across all other EU member states the workforce will age rapidly over the next 40 years, bringing with it the risk of increasing MSD prevalence. In other words, the impact of MSDs on work disability can be anticipated to intensify rather than diminish. Two thirds of the European workforce with MSDs reported that pain was responsible for a significant reduction in their quality of life, and 49% were limited because of pain in the kind of work they were able to perform (Bevan et al. 2009). MSP poses extra challenges, because it seems to be more disabling than single-site pain both in population-based surveys and in occupational samples.

7.1.3. Association of multiple-site musculoskeletal pain with psychosocial factors at work and mental stress over time

Many reports recommend that consideration of pain at several sites simultaneously is preferable to the assessment of one pain location in isolation. Nonetheless, most studies have traditionally examined prognostic factors of single-site pain (Mallen et al. 2007) and the risk factors of the occurrence of MSP are not well known. The need to provide information on why pain tends to occur at multiple sites and to examine the occurrence of MSP over time has recently been emphasized (Croft et al. 2007). Many of the psychosocial factors at work have been found to be associated with musculoskeletal pain, mostly in cross-sectional studies. However, in cross-sectional studies, it is not possible to estimate the timing of determinant and outcome, as the both are assessed at the same time. The need for conducting longitudinal studies in this area is evident (Macfarlane et al. 2009).

Since no systematic differences between the intervention and control group in our CRT were found in MSDs, MSP or perceived physical workload, the groups were pooled for analysis as a two-year longitudinal study (IV). There were two hypotheses, with reversed directionality. First, the intention was to determine whether psychosocial factors at work...
and mental stress predicted the development of MSP over time, and second, whether MSP could predict the occurrence of psychosocial factors at work and mental stress. The reciprocal analyses were based on the finding of Leino and Magni (1993) who examined metal industry workers. They found that symptoms related to mental stress predicted an increase in a sum score of musculoskeletal pain at several sites, and respectively, the pain sum score predicted an increase in stress symptoms.

In etiological longitudinal studies, usually the relation between an exposure measured at baseline and the occurrence or change of the outcome during the follow-up period is examined. In this work, it was possible to make use of two different types of longitudinal analyses in assessing relationships between the measures. One of these examined the situation at three-month intervals (the GEE) and the other described them using the total two-year follow-up period (trajectories). The use of trajectories also enabled the examination of changes in psychosocial factors at work in relation to changes in MSP over time.

The 3-month prevalence of MSP (defined as pain at ≥3 of seven sites) varied between 50-61% during the two-year follow-up. According to this definition, the workers in the category of no MSP could still have pain at 1 to 2 sites. A quarter of the workers reported pain in at least two sites at every nine assessed time points. This is noteworthy because having pain at one site is shown to increase the risk of developing pain at other sites and the risk increases with the number of initial painful sites (Croft et al. 2007; Kamaleri et al. 2009). The average number of pain sites appears to be set already by age 20 and little variation seems to occur thereafter (Croft 2009; Kamaleri et al. 2009). However, it was found that some variation, even a decrease, in the occurrence of MSP in working age is possible. Trajectory analysis identified four trajectories of MSP prevalence and it was observed that 19% of the workers belonged to the trajectory with a descending pattern in the prevalence of MSP.

The three analyses support both of the study hypotheses. First, in time-lagged analysis, psychosocial factors at work predicted MSP reported three months later, and vice versa, MSP predicted adverse psychosocial factors at work after adjustment for covariates. The risk estimates were comparable in both directions with the exception of hurry at work,
which predicted MSP but was not predicted by MSP. Secondly, poor co-worker relationships, mental stress and hurry at baseline predicted belonging to the High MSP trajectory. In addition, MSP at baseline predicted belonging to the trajectories of Ascending low job control and mental stress. Finally, the adverse development in most psychosocial factors was associated with belonging to the High and Ascending MSP trajectories. This reciprocal linkage complicates conclusions of the causal nature of the relationships between these factors. Two possibilities seem to exist: this finding either reflects two processes that are mutually and serially dependent in time or there is/are some common underlying factor(s).

With regards to the relationships between mental stress and MSP, these current findings basically replicate those reported by Leino and Magni (1993) with a somewhat different measure of MSP and in a different occupational setting. As far as I am aware, no systematic reciprocal analyses with pain symptoms and psychosocial factors at work have been carried out before. This present study seems to be the first to examine developmental patterns of MSP and of psychosocial factors at work. Overall, few longitudinal studies exist in this subject area among general population or occupational samples.

Differences in study designs, samples, and measures of outcomes and determinants, complicate the comparison of these results with those of previous studies. However, our findings are in accordance with some earlier reports in line with our first hypothesis. Leino and Hänninen (1995) reported that after adjustment for physical workload, poor social relationships at work and poor job control predicted an increase of pain and musculoskeletal clinical findings in the neck and upper limbs, low back, and lower limbs in a 10-year follow-up. Dissatisfaction with support from colleagues or supervisors was found to increase the risk of future episodes of forearm pain that commonly co-occurred with other regional pain (Macfarlane et al. 2000). In this study, poor co-worker relationships at baseline predicted belonging to the group with a constantly high prevalence of MSP. The time-lagged analysis showed that low supervisor support and low job control increased the risk for MSP about two-fold. It may be that in small work communities where work is done in close co-operation, there is an emphasis on the importance of good social relationships for well-being.
In these GEE-models, mental stress and hurry predicted MSP. It was also found that mental stress and hurry at baseline predicted reporting chronic MSP, a finding in support of earlier results. Nahit et al. (2001) conducted a cross-sectional study among newly employed workers (n= 1081, median age 23 year) and observed that those who perceived their work as stressful and hectic for most of the time had an increased risk of pain at multiple sites. Later, based on the same study sample, they reported that high levels of individual psychological distress and adverse work-related psychosocial factors predicted the onset of musculoskeletal pain at a one-year follow-up with similar effects across anatomical sites (Nahit et al. 2003). The median age (47 years) in the present sample was higher. It could be that regardless of age, mental stress and hurry might increase the risk of MSP.

In cross-sectional studies, women, smokers, overweight subjects and those with low physical activity have reported a greater number of pain sites (Walker-Bone et al. 2004; Kamaleri et al. 2008a). In the present female sample, smoking had no effect on the development of MSP. Risk estimates for overweight were increased, but not statistically significantly. Instead, perceived physical workload and age predicted an increase and a constantly high prevalence of MSP (unpublished results).

Mental stress and other psychosocial factors may be linked to MSDs with many pathways. Psychosocial factors may have a direct influence on the loading on the spine through changes in postures, movements, and exerted forces. Psychosocial factors may trigger chemical and physiological responses. Increased hormonal excretion or muscle tension may influence pain perception and in the long-term lead to MSDs. Psychosocial factors can influence awareness, and alter the ability to cope with the pain and illness and possibly increase the likelihood of reporting of symptoms (Bongers et al. 1993; Sauter and Swanson 1996; Davis and Heaney 2000; Hoogendoorn et al. 2000; Bongers et al. 2002).

This study raises the question about the mechanism behind the finding that the occurrence and development of MSP over time predicts the occurrence and development of adverse psychosocial working conditions. It is perhaps noteworthy that both measures were based on subjective perceptions. There might be common underlying factor(s), and these will require further study.
7.2. Methodological aspects

7.2.1. Validity of the CRT

The CRT (study I) is included in three systematic reviews focusing on the effectiveness of workplace interventions for LBP and neck pain, one by Dutch researchers (Driessen et al. 2010) and the other two by a Nordic research group in the Cochrane collaboration (Aas et al. 2009a; Aas et al. 2009b). In these reviews, the risk of bias is assessed by using the 12-item Cochrane Back Review Group criteria list. The quality of the present study was evaluated to be high (scores 9/12, Driessen et al. 2010). The criteria of blinding were not fulfilled. In our view it is not possible to conduct a PE intervention in a blinded manner. However, the baseline data on all outcomes and measures were collected before randomization, so that the workers participating in the study or the researchers ('care providers') were not conscious of the study arm to which the workers would be allocated. After randomization, both the workers and researchers were aware of the allocation. The researchers were blinded with respect to the questionnaire data during the data collection, and data analysis was started only after all the follow-up data had been collected.

As an additional requirement is that those assessing outcomes ('outcome assessors') should be blinded about the study arm. The outcomes were based on self-reports collected by questionnaires. It is conceivable that the workers in the intervention group may have been sensitized to perceive and report their MSDs and psychosocial factors at work. The magnitude of this possible bias is difficult to assess.

Randomization was based on an assignment algorithm generated by a computer. An individual otherwise unconnected with the implementation of the intervention was responsible for the randomization. Randomization was successful and good comparability between the groups persisted throughout the study. This was true even in spite of the organizational reforms carried out in two cities, because the study design guaranteed a parallel proceeding in time of both study arms within each series of kitchens. Stratification by area and type of kitchen ensured balanced clusters with respect to baseline characteristics.
Data were analysed according to the intention-to-treat principle. Three kitchens dropped out after the randomization. No information after the baseline questionnaire on these kitchens was available, and it was not possible to make any further analyses on them. This situation is remotely analogous to the case where the patient dies before starting the medication/treatment. It is not generally considered that a situation such as that violates the intention-to-treat principle. All three dropout kitchens were randomized to the intervention group. In one kitchen, the study was considered too cumbersome. Otherwise the reasons were coincidental. The amount of dropouts was minor in relation to the total number of kitchens. At least 70% of the workers remained employed in the same kitchen throughout the study. Despite the staff turnover, the groups remained similar through the intervention phase with regard to assessed potential confounders. All these observations indicate that selection or attrition bias did not threaten the validity of the study.

There was a relatively large sample size and sufficient statistical power. The clustered nature of the data was taken into account in the power calculation and in the analyses of the results. Because this intervention was targeted at the kitchen (community) level, we used repeated cross-sectional analyses of the open population. This approach has been recommended as being more appropriate than cohort analyses for measuring the effectiveness of interventions in the community. The disadvantages of this approach have also been pointed out. The analyses possibly include workers who receive limited exposure to the intervention or that elements of the intervention diffuse to other communities (Ukoumunne and Thompson 2001; Atienza and King 2002). However, the present results in the open population were similar to those in the cohort analysis among subjects who remained in the same kitchen throughout the study.

There were very high response rates, participation in the workshops was good, and no dropouts occurred during the intervention, indicating good compliance. If the workers changed kitchen, they were asked not to talk about the study process. Only two workers were transferred from an intervention kitchen to a control kitchen during the intervention. Thus, one can state that contamination was probably minor. Co-interventions/external changes were similar in the intervention and control groups. The most prominent external change was the re-organization of food service in two of the participating cities during the study. The intervention and control group were in the same phase of the changes.
throughout the study. On average, series of four intervention and four control kitchens entered sequentially in calendar time. Quality control based on regular meetings was applied to ensure that there was similarity in the working methods between the researcher teams working in the different cities. In addition, a project coordinator participated in the workshops and observed the working of the researchers and provided them with feedback.

The inclusion of a 12-month post-intervention follow-up is also among the strengths of this study. However, it may be that the intervention was not intensive enough. Due to financial and time constraints, the follow-up period was limited to one year. An even longer follow-up would have been needed to note the impacts on the musculoskeletal system and to examine the persistence of the adverse changes in psychosocial factors at work. Given the episodic nature of MSDs, the 3-month prevalence measures may not have been optimal to capture a change in the frequency of bouts of MSDs. The measures of local musculoskeletal fatigue during the past seven days were more sensitive. However, no effect was detected using either fatigue measure.

A source of bias might arise from the fact that the workers had an active role in implementing the ergonomic changes and the outcome assessments were based on their subjective reports. It is conceivable that their involvement in an intervention program increased the workers’ awareness of both ergonomics as well as musculoskeletal problems. Being involved in the intervention may have encouraged the workers to develop unrealistic expectations for the intervention to improve ergonomics and psychosocial work environment. This might have been reflected via the increase in the adverse changes in psychosocial factors at work.

The personal visits of a researcher to each of the kitchens encourage the workers to complete the questionnaire probably was one of the reasons for the excellent response rates. The researcher also documented changes in the control kitchens based on short interviews. The visits can be interpreted as a kind of intervention for the control kitchens, but their potential contribution to the results remains speculative. The visits may have increased awareness of MSDs also in the control kitchens, which could have reduced information bias regarding musculoskeletal outcomes. Documentation of the changes during the visits may have activated the workers in the control kitchens to undertake more
changes, which could have diluted the overall effect. Still, the difference in the number of
changes made in the intervention kitchens and those that occurred spontaneously in the
control kitchens (402 vs. 80) is considerable. On the other hand, it has been recommended
that the groups should be dealt with as similarly as possible, except for the intervention
itself, to avoid the 'Hawthorne effect' (Westgaard and Winkel 1997; Shannon et al. 1999).

**Intervention process**

The intervention process has been carefully evaluated and reported (Pehkonen et al.
2009c). The process evaluation was based on research diaries, questionnaires, and focus
group interviews. The intervention model and the participatory approach as such were
found to have been successful, well accepted and perceived as motivating. The workers’
ergonomics knowledge level increased and, in the workers’ own words, they developed an
'eye for ergonomics' with respect to their own work and that of others. Interestingly, most
of the workers felt that the intervention had had a positive effect on physical load and
musculoskeletal health, although the results did not support the hypothesis.

The workers conveyed that the feeling of togetherness within their own kitchen had
improved and that the intervention had facilitated discussion among and asking for help
from co-workers. The rotation of the workshops in different kitchens was felt to be
beneficial in enabling learning from each other's good practices. On the other hand, the
workers were dissatisfied with the support from the management and collaboration
between the kitchens, especially in one of the cities which was in the process of
implementing organizational reforms. The more satisfied the kitchens were with the
support from management, the better were the impacts of the intervention as evaluated by
the workers. The workers expected also more support from the researchers and technical
staff. A total of 113 planned changes were not completed. The most common reasons for
non-completion of changes were lack of motivation or time. The major observed obstacles
in improving kitchen ergonomics were passivity and resistance to change (Riihimäki
2005b).
7.2.2. Clinical importance and generalization of the CRT findings

About 60% of all eligible kitchens took part in the study. Of the 80 non-participating kitchens, some kitchens collectively refused to participate. In some cases, the decision of refusal was administrative (e.g. made by the manager of the nursery or the headmaster of the school), and in some kitchens at least one-third of the workers individually refused to take part. In other cases, participation was withdrawn since there was going to be a major reconstruction in the kitchen. The non-participating kitchens did not differ from their participating counterparts in terms of size or location. However, no additional information on the workers employed in the non-participating kitchens was available. For example, it is possible, that physical or mental overstrain or poor social relationships at work could have influenced the willingness to participate in a time-consuming intervention study. It seems less likely that the workers in the non-participating kitchens would have had different levels of pain or higher exposure to physical and/or mental workload compared to those in the participating kitchens.

The results indicate that it is difficult to influence the heavy overall mental and physical workload of kitchen workers without making structural changes in the kitchens and redesigning whole work processes. There was no possibility to affect the basic design of the kitchens or the amount of work by intervention. The ergonomic changes of the present study mostly concerned micro-ergonomics. It may be that to obtain favourable effects on the musculoskeletal health of the workers, a more comprehensive redesign of work organization and processes is needed, taking more account of workers' physical and mental resources (macro-ergonomics). The development of work should be a continuous activity and it requires smooth collaboration between workers, management, planners, architects, and technical staff.

The results can be generalized to other municipal kitchen workers. Although our study has been evaluated to have a low risk of bias (Driessen et al. 2010), care must be taken in generalizing the results beyond the target population. The amount of high quality RCTs or non-randomized trials is insufficient to drawing conclusions of the utility of the PE approach aimed at preventing MSDs. There is a need for further trials to elucidate this issue.
7.2.3. Methodological aspects in studies of multiple-site musculoskeletal pain

In the cross-sectional study (III), both 3- and 12-month reference periods were used to assess the prevalence of musculoskeletal pain. Different reference periods did not materially affect the prevalence of pain. This is in accordance with previous Nordic studies (Ørhede 1994). The 3-month reference period was considered more reliable due to the shorter required span of memory, and was used in further analyses as also recommended by Ørhede et al. (1994). The 3-month reference period was used also in all other studies (I, II, IV). Illustrations showing the area of interest were used in the questionnaire. A verbal description might leave too large a share for individual opinion on what represents the neck, shoulder, forearm/hand, and low back. This probably enhanced the reliability of reporting. It could be argued that a similar approach might have been preferable for hip pain as well. On the other hand, van den Hoven et al. (2009) recently assessed the agreement between showing the participants a manikin to locate the pain sites and a self-administered questionnaire on musculoskeletal pain. They concluded that the manikin gave similar findings on the prevalence of pain as written questions and they stated it could be a good alternative for written questions only. However, the manikin revealed higher pain prevalence rates. It could be that the use of a manikin to illustrate the area of body site in addition to a written question may have lowered the threshold for reporting pain in this study. One limitation in these studies was the lack of intensity and frequency measures of pain.

The use of a trajectory analysis was a novel approach in analyzing MSP. In the field of psychology, this method is commonly used, but it has not often been applied in the area of musculoskeletal research. Trajectory analysis is developed for analyzing longitudinal data and identifying different groups of individuals within a population who tend to have a similar profile over time (trajectories). All available data points during a given period are used. Even though the prevalence of musculoskeletal symptoms may be similar at different time points in longitudinal studies, there is often high variation in pain reporting over time at the individual level (Takala et al. 1992). Trajectory analysis was able to make the maximum use of the data, examining the development of MSP as well as that of psychosocial factors at work over time.
In conducting trajectory analysis, it has been recommended that measurements should be available in at least half of the assessed time points if one wishes to reliably assess group membership probabilities, and in at least three time points to detect trajectories of quadratic shape (Kokko 2004). Thus, only subjects with observed values of MSP in at least four time points of the nine possible were included. The sensitivity analysis, where we dropped out 20 individuals with mean posterior assignment probabilities lower than 0.60, did not change the basic result of the number or shape of the MSP trajectories. According to the mean posterior assignment probabilities, 69-92% of the subjects were correctly assigned to the trajectories. In addition, the assignment probabilities for all psychosocial work factor trajectories were over 0.70, as recommended (Nagin 2005).

The cut-off point for MSP is not well established. By trajectory analysis, the development of MSP was first analyzed with MSP as a continuous variable. Forty-two per cent of the workers were assigned to the trajectory comprised of those reporting pain in at least three sites of seven. We then dichotomized MSP and used ≥ 3 pain sites as a cut-off point. The results of the sensitivity analysis by using ≥ 4 pain sites as the cut-off point did not change the basic result regarding the number and shape of the trajectories.

Although the sample was large enough to permit trajectory analysis (Kokko 2004), it was relatively small for the assessment of risk, increasing imprecision of the estimates. Among the limitations of this study could be the assessment of psychosocial factors at work by single items. A single-item measure of mental stress has proved a valid measure, however (Elo et al. 2003). All of the measured psychosocial factors at work have been identified as risk factors for MSDs. The present study sample consisted of women in a single occupational group. Hence, the generalizability of the results may be limited and can with confidence be extended to other occupations where there are small work communities, a high physical workload, and tight time constraints at work. Similar analyses among men would be interesting and worthy of further study.

7.2.4. Self-reported outcome measures

All of the outcome measures were based on self-reports collected by questionnaires. Self-reported symptoms collected by questionnaires have largely been basic data source in epidemiologic research regarding MSDs. Questionnaires offer a quick and inexpensive
data collection on an individual basis from large samples. The use of self-reported pain has been proposed to be the most valuable approach to measure outcome in population-based surveys (Schierhout and Myers 1996). The International Association for the Study of Pain defines pain as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage' (Merskey and Bogduk 1994). Pain may also occur in the absence of tissue damage or any likely pathophysiologic cause. Pain is always a subjective sensation. Yet, pain research has recently provided new interesting findings based on brain imaging studies that have identified within-subject relationships between regional pain activity and subjective pain reports. However, the subjective report will probably remain the single most reliable index for the magnitude of pain (Coghill et al. 2003).

The majority of research reports on the psychosocial work environment have been based on self-reported assessments (Theorell and Hasselhorn 2005). The questions used in this study were from a validated Occupational Stress Questionnaire (Elo et al. 1992; Elo et al. 1994). The problem of self-reported data is substantial in cross-sectional studies when both psychosocial environment and health are described by self-reports and when both are assessed concurrently. It is not clear to what extent self-reports of psychosocial work factors reflect individual characteristics and to what extent they reflect true environmental conditions. It has been argued that subjectivity bias may explain most of the observed associations between psychosocial working conditions and health. Some people may have a tendency to overreport problems in the environment and also in their own health (negative affectivity). Similarly, some may underreport problems in both psychosocial environment and health (denial) (Theorell and Hasselhorn 2005). Nahit et al. (2001) discussed that one way to objectively measure an individual's psychosocial working conditions could be to ask a co-worker or manager to do the assessment. Work unit aggregated scores have been used to assess job strain among Finnish public sector employees (Laine et al. 2009). Overcrowding in hospital wards has recently been used as a proxy for mental strain of hospital staff (Virtanen et al. 2008). However, one may argue that in some respects, the worker's own assessment is the most valid estimate, particularly if the psychosocial work environment as perceived by the worker is being enquired. In the present situation, it is possible that the awareness of both musculoskeletal pain and
psychosocial factors increased during the research period and lead to a more critical evaluation by the workers.

A self-administered questionnaire is still the most widely used method also for assessing physical workload (Barrero et al. 2009; Burdorf 2010). The reliability and validity of physical workload assessments based on self-reports have been often criticized (Viikari-Juntura et al. 1996; Buchholz et al. 2008; Burdorf 2010). In some previous studies, self-reported physical workload has been shown to be a powerful predictor of MSDs and physical functioning (Miranda et al. 2001; Leino-Arjas et al. 2004). Questionnaires are also useful in identifying relative differences in exposure among occupational groups and rank the groups according to their overall level of physical workload (Viikari-Juntura et al. 1996; Burdorf 2010). Direct measurements are costly and their laboriousness makes them less feasible for use in epidemiologic studies. In a systematic review Takala et al. (2010) recently evaluated observational methods assessing biomechanical exposures at work. They found that though many methods exist, none of those evaluated appeared to be superior to the others. Only some of the methods have been systematically tested for validity, repeatability and feasibility.

7.3. Study findings in relation to the theoretical framework of the study

Karsh (2006) and Huang et al. (2002) have reviewed the theories and models of work-related MSDs causation. These theories share many similarities. All of them emphasize that psychological or physical exposures lead to responses that are moderated by individual factors. Most of the models propose a feedback mechanism or cascading effects. One common feature to all the theories is that many important aspects are not defined, e.g. what is the magnitude and duration of an exposure that leads to certain responses, or the length of the latency period between exposure and response. Some theories contribute to the understanding of the relationships between psychosocial factors and MSDs. Carayon et al. (1999) underline the role of psychophysiological mechanisms (e.g. the effects of stress hormones, changes in regional blood flow). Workstyle is featured in the Feuerstein (1996) model. Melin and Lundberg (1997) highlighted the influence of demands outside the workplace. However, empirical support to the schemas of the theories
is limited and further research is needed to validate the multiple pathways that are proposed.

The current study was based on the ecological model of Sauter and Swanson (1996), which incorporates three components: psychosocial, biomechanical, and cognitive. The cognitive component related to the attribution or interpretation of symptoms is a unique aspect, as well as the proposition that tissue damage is not a necessary condition for the development of symptoms. The model suggests that a complex cognitive process, which involves the detection and attribution of symptoms, mediates the relationships between biomechanical strain and the development of MSDs. The development of symptoms is seen as a flexible and interpretative process, influenced by both the social context and the subject's own experience.

The results of this study support the importance of this cognitive component. Pain and psychosocial factors seem to be reciprocally linked together. There are individual differences e.g. in pain sensitivity or the manner of experiencing the psychosocial working environment. Many factors such as coping mechanisms, beliefs, motivation, past pain history, other life experiences, personality, life situation, etc. can modify these individual perceptions. The present results suggest that pain modifies the perceptions of psychosocial factors, and that psychosocial factors modify pain perception. The model (Sauter and Swanson 1996) shows these reciprocal links between MSDs, work organization and psychological strain mediated by the cognitive process.

The perception of pain may also modify perceived physical workload. Physical activity, in terms of biomechanical exposure at work or leisure time, may influence pain perception. In the model (Sauter and Swanson 1996), the link between MSDs and biomechanical load is neither direct nor reciprocal. The possible reciprocal associations between perceived physical workload and pain experiences would be worthy of further study. If that link would prove reciprocal, it would further strengthen the importance of individual sensations and cognition in the development of MSDs. As a corollary, interventions should focus on secondary and tertiary prevention, to guide people to manage and control disorders whenever they appear.
8. CONCLUSIONS

While this PE intervention was successful in engaging the kitchen workers to evaluate and improve the ergonomics of their daily work, no systematic differences in any health outcomes were found between the intervention and control groups during the intervention or during the 12-month post-intervention follow-up. The intervention did not reduce perceived physical workload. The effects on psychosocial factors at work were unfavorable. These adverse changes were mainly due to a joint effect of the intervention and unconnected organizational reforms of foodservice in two of the participating cities. This may partly explain why the intervention did not have any effect on the occurrence of MSDs. The occurrence of MSP among female kitchen workers was high and more common than single-site pain. Psychosocial factors at work and mental stress strongly predicted MSP over time and, *vice versa*, MSP predicted psychosocial factors and mental stress. Such reciprocality of the relationships suggests either two mutually dependent processes in time, or some common underlying factor(s).

9. IMPLICATIONS OF THE RESULTS

The challenges in MSD research and in preventive work include the multifactorial etiology, the high occurrence of many MSDs and particularly that of MSP, and the episodic, recurrent and subjective nature of musculoskeletal pain. The workforce is ageing in the industrialized countries. At the same time, there is pressure to extend working careers beyond the current retirement age. Interventions that focus on maintaining employees' work ability, controlling sick leaves, and supporting return to work are needed.

The results do not support the usefulness of the studied PE intervention in preventing MSDs or in changing unsatisfactory psychosocial working conditions. If organizational changes are expected to occur, it is essential to take caution with the implementation of other workplace interventions at the same time. Developing ergonomics should be a continuous activity in fluent collaboration with planners, architects, technical staff,
management, and workers themselves as the best expert in their own work. Further high quality trials are needed to elucidate the effectiveness of ergonomics interventions. The current study showed that conducting RCT at workplaces is feasible.

The evaluation and prevention of pain at multiple anatomical sites might be useful in addition to considering single-site pain, both in the daily work of occupational and healthcare professionals, in epidemiological research, and in further intervention studies. Since MSP and psychosocial factors at work seem to be strongly linked together, parallel assessment of both measures is recommended. As subjective perceptions, they may share some common underlying factors, which need to be clarified in further studies. More objective methodological approaches for assessing psychosocial factors at work and of MSDs are also needed.
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