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IRMELI PEHKONEN

Evaluation and Control of Physical Load Factors at Work

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Editors:
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Faculty of Health Sciences

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Author's address:	Finnish Institute of Occupational Health Topeliuksenkatu 41 a A FI-00250 HELSINKI, FINLAND E-mail: irmeli.pehkonen@ttl.fi
Supervisors:	Esa-Pekka Takala, M.D., Ph.D. Finnish Institute of Occupational Health
	Professor Eira Viikari-Juntura, M.D., Ph.D. Finnish Institute of Occupational Health
	Professor Veikko Louhevaara, Ph.D. University of Eastern Finland, Department of Physiology
Reviewers:	Nils Fallentin, Ph.D. Liberty Mutual Research Institute for Safety MA 01748, USA
	Professor Clas-Håkan Nygård, Ph.D. Tampere School of Public Health University of Tampere Tampere, Finland
Opponent:	Professor Seppo Väyrynen, TkT Department of Industrial Engineering and Management University of Oulu Oulu, Finland

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ABSTRACT

Choosing a valid exposure assessment strategy and method is essential while carrying out intervention studies. In this thesis, a procedure was developed to evaluate the validity, repeatability, utility, and usability of observation methods to assess musculoskeletal exposure, and it was applied on 30 observational methods. In addition, a new method was developed for the assessment of musculoskeletal load from video recordings before and after the intervention in kitchen work, and its repeatability, validity, and usability was evaluated. The method detected several changes in the physical load due to the interventions. The direction of the changes was in line with those of the expert assessments. In ergonomic intervention studies, the intervention process itself has rarely been evaluated. In this thesis, the feasibility and effects of an intervention process carried out in 59 municipal kitchens was evaluated using questionnaires, focus group interviews, and research diaries. The workers' knowledge and awareness of ergonomics increased and over 400 changes were implemented. However, the workers wished for more support from the management and more practical tools for development. In addition, the effects of the changes in self-perceived and observed work load on shoulder symptoms were studied. The reduction in the strenuousness of the work tasks perceived as physically the most loading and the observed reduction in lifting was associated with a lower risk for future shoulder symptoms. These results indicate that more information on methods as well as sampling strategies should be provided to the users to help them choosing the most appropriate method. The new video-based observation method proved to be applicable for variable and fast-changing work. In developing an intervention process, the data on knowledge, attitudes, and behaviours of the target population, and data on the context in which the intervention will be carried out should be utilized. A new finding in this dissertation was that reduction in lifting showed beneficial protective effects on the shoulder. Hence, work tasks that include lifting should be especially targeted both in risk assessment and in the selection of preventive measures.

National Library of Medicine Classification: WA 440, WE 140
Medical Subject Headings (MeSH): Human engineering; Intervention studies; Occupational Exposure; Musculoskeletal diseases; Workload; Lifting; Shoulder; Risk factors; Observation; Video Recording

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TIIVISTELMÄ

Interventiotutkimuksissa on tärkeää valita luotettava arviointistrategia ja -menetelmät. Tässä väitöskirjatutkimuksessa tunnistettiin yhteensä 30 liikuntaelinten kuormituksen arviointiin tarkoitettua havainnointimenetelmää ja kehitettiin toimintatapa menetelmien luotettavuuden, toistettavuuden, hyödyllisyyden ja käytettävyyden arvioimiseksi. Lisäksi kehitettiin uusi videopohjainen havainnointimenetelmä keittiötyön kuormituksen tutkimiseen, ja arvioitiin menetelmän luotettavuutta, toistettavuutta ja käytettävyyttä. Menetelmällä havaittiin intervention seurauksena tapahtuneita kuormituksen muutoksia. Tulokset olivat samansuuntaisia asiantuntijoiden arvioiden kanssa. Ergonomiainterventioissa itse interventioprosessi on ollut arvioinnin kohteena vain harvoin. Tässä tutkimuksessa arvioitiin prosessin toimivuutta ja vaikuttavuutta 59:ssa kunnallisessa ammattikeittiössä. Tietoa kerättiin kyselyillä, ryhmähaastatteluilla ja tutkimuspäiväkirjoilla. Työntekijöiden ergonomisen tiedon taso ja tietoisuus ergonomiasta lisääntyivät ja yli 400 muutosta toteutettiin vuoden interventiovaiheen aikana. Työntekijät olisivat kuitenkin toivoneet enemmän tukea johdolta ja käytännönläheisempiä kehittämismenetelmiä. Lisäksi selvitettiin työntekijöiden kokeman ja tutkijoiden havainnoiman kuormituksen vähenemisen vaikutuksia myöhempiin olkapäävaivoihin. Sekä koetun kuormituksen väheneminen fyysisesti raskaimmissa töissä että havainnoidun kuormituksen väheneminen nostotyössä olivat yhteydessä pienempään olkapäävaivojen riskiin. Tulokset osoittavat, että menetelmien käyttäjät tarvitsevat lisää tietoa havainnointimenetelmistä ja arviointistrategioista, jotta he pystyisivät valitsemaan parhaan mahdollisen menetelmän kuhunkin käyttötarkoitukseen. Uusi havainnointimenetelmä osoittautui käyttökelpoiseksi vaihtelevan ja nopeatempoisen työn arviointiin. Interventioprosessia suunniteltaessa tulisi hyödyntää tietoa kohdejoukon ergonomiatiedon tasosta, asenteista, ja käyttäytymisestä sekä toimintaympäristöstä, jossa interventio toteutetaan. Tämän tutkimuksen uusi löydös oli, että nostamisen vähentäminen vähentää olkapäävaivojen riskiä. Siten, sekä kuormituksen arvioinnissa että ehkäisevien toimenpiteiden suunnittelussa pitäisi kohdistaa huomio erityisesti työtehtäviin, jotka sisältävät runsaasti nostamista.

Yleinen suomalainen asiasanasto (YSA): ergonomia; interventio; tuki- ja liikuntaelimet; olkapäät; fyysinen kuormittavuus; työliikkeet; nostaminen; keittiöt; arviointi; havainnointi; itsearviointi; riskitekijät; kuormitus; videokuvaus

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Espoo, Valentine's Day 2010

Irmeli Pehkonen

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on data presented in the following articles, referred by their Roman numerals:

I Takala E-P, Pehkonen I, Forsman M, Hansson G-Å, Mathiassen S E, Neumann W P, Sjøgaard G, Veiersted K B, Westgaard R, Winkel J. Systematic evaluation of observational methods assessing biomechanical exposures at work – A review. Scandinavian Journal of Work, Environment and Health 2010; 36: 3-24.

II Pehkonen I, Ketola R, Ranta R, Takala E-P. A video-based observation method to assess musculoskeletal load in kitchen work. The International Journal of Occupational Safety and Ergonomics 2009; 15: 75-88.

III Pehkonen I, Takala E-P, Ketola R, Viikari-Juntura, Leino-Arjas P, Hopsu L, Virtanen T, Haukka E, Holtari-Leino M, Nykyri E, Riihimäki H. Evaluation of a participatory ergonomic intervention process in kitchen work. Applied Ergonomics 2009; 40: 115-23.

IV Pehkonen I, Miranda H, Haukka E, Takala E-P, Ketola R, Luukkonen R, Riihimäki H, Viikari-Juntura E. Prospective study on shoulder symptoms among kitchen workers in relation to self-reported and observed work load. Occupational and Environmental Medicine 2009; 66: 416-423.

Contents

TABLES:

FIGURES:

ABBREVIATIONS

CI	Confidence Interval
EMG	Electromyography
KILA	Kitchen Intervention work Load Assessment
MSD	Musculoskeletal Disorder
OR	Odds Ratio
PE	Participatory ergonomics

Abbreviations / acronyms of exposure assessment methods are explained in Table 6.

1 Introduction

It is generally acknowledged that working life has changed during the last three decades in Finland and also in other industrialized countries: the proportion of heavy labouring and manufacturing has declined, whereas working in the service and information sectors has increased. In addition, work life is nowadays psychologically more demanding and hectic than before. However, this shift does not mean that physically demanding jobs are disappearing: e.g. in Finland, every fourth worker still perceives his/her work as being physically strenuous. Particularly service, healthcare and social sector are perceived physically strenuous by women and manufacturing by men (Perkiö-Mäkelä et al. 2006). Even though the physical demands of work have decreased, the occurrence of musculoskeletal disorders (MSDs) is still at a high level, and MSD-related sick leaves and disability pensions have continued to increase. Work-related factors are known to cause and worsen MSDs, and therefore it is important that workplace preventive measures are taken seriously (Punnett and Wegman 2004).

Ergonomic interventions have been implemented aiming to reduce physical work demands and prevent MSDs (Silverstein and Clark 2004). During recent decades, the importance of workers' participation in intervention processes has been realized, and interventions have been provided them with greater possibilities to influence decisions concerning their work. In a participatory approach, the workers are considered as the main actors in the development of work. The benefits of this approach are that the workers utilize their knowledge and experiences, the participants learn from each other, and furthermore, this approach should make the workers more committed and amenable to accept the changes (Wilson 1995). However, in order to obtain systematic information on intervention studies, their methodology still needs to be developed. Typically, the evaluation of an intervention study focuses on the quantitative outcomes (i.e. changes in health outcomes and/or exposures), whereas the evaluation of the intervention process itself, which may often reveal valuable information about the interpretation of the outcome results, is seldom carried out (Whysall et al. 2006). Moreover, in intervention studies, the changes in exposures and health outcomes have usually been reported separately. However, it would be important to know whether the reduction in some exposure that is considered to be a risk factor for some disorder, also would reduce incidence of a disorder.

In order to carry out effective ergonomic interventions, obtaining valid information on exposures is a primary requirement. Several exposure assessment methods have been developed for assessing musculoskeletal load, i.e. to identify risk factors, to target preventive actions and to assess the effects of interventions (Li and Buckle 1999, David 2005). However, partly due to the changes from mono-task jobs to more varied multi-task jobs, in which workers often perform a large number of variable tasks during a work shift, previous exposure assessment methods may not be the most useful to assess physical work load of those tasks. For example, most observational methods have initially been developed for studying monotonic work tasks repeated in predefined sequences. Therefore, new methods suitable for assessing dynamic work are needed.

One common occupation with a high variety of different tasks is professional kitchen work, which employs in Finland approximately 3 % of the workforce (Statistics Finland 2005). Kitchen workers have a high prevalence of musculoskeletal disorders and in Finland they are among the top 5 occupations with the highest sickness absence and disability pension rates (Forma 2004, Vahtera et al. 2008). Especially in the municipal sector, the workers are mainly middle-aged women with several years' employment in kitchen work (Hopsu et al. 2003). Of municipal occupational groups, kitchen workers reported most often high physical work load, fast work pace, low correspondence between knowhow and work demands, need for education, and fear of temporary dismissals or notices (Forma et al. 2004). Nonetheless, very little systematic research has been done on this occupational group. For example, kitchen work has rarely been a target for ergonomic intervention studies.

2 Review of the literature

2.1 RELATIONSHIP BETWEEN WORK-RELATED EXPOSURES AND MUSCULOSKELETAL DISORDERS: CONCEPTUAL MODELS

Musculoskeletal disorders are a major cause of occupational disability in industrial countries. They are often long-term and recurrent, and therefore are responsible for considerable productivity losses. According to the definition of World Health Organization (WHO 1985), work-related musculoskeletal disorders are disorders or diseases, which may be caused, aggravated, accelerated, or exacerbated by workplace exposures. Starting from the model proposed by Rutenfranz (Rutenfranz 1981), several theoretical models have been presented explaining the pathways from the risk factors to their health outcomes. In their review, Karsh et al (2006) described and compared nine previously developed models and — using them as a basis — developed a composite model. Huang et al. (2002) described and evaluated three models of occupational stress and health and six models of work-related MSDs. Most of the models emphasize that the etiology of symptoms is multi-factorial. Both physical and psychosocial exposures impose doses within the body, which cause both biological and behavioral responses. However, the dose is modified by individual factors. Most of the models propose the existence of feedback mechanisms or cascading effects. If the dose is greater than the individual capacity, then the effects will start a cascade of responses leading eventually to MSDs. However, the individual capacity is not constant: the musculoskeletal system can adapt to the external loads over time. Moderate loads will increase the capacity (training effect) and too low loading will result in reduction of the capacity (Armstrong et al. 1993). The effect of the exposure on a risk factor may be immediate (such as a traumatic injury after an accident) or the symptoms may develop after a longer induction period. The models have not, however, included such important factors like magnitude and duration of exposure and latency periods (Pinder and Wegerdt 2008).

The theoretical basis of this study is the model developed by Sauter and Swansson (Fig.1) (Sauter and Swanson 1996), which was initially developed for office workers working at a computer. This model incorporates and intergrates biomechanical, psychosocial, and cognitive components, and therefore it was considered useful also for kitchen work. The model was modified for the purpose of the studies of this thesis by including aspects of work done in professional kitchens. In addition, in the original model, it was assumed that psychosocial strain only impacts on the biomechanical strain, but in the modified model it was postulated that the effects may be bidirectional. In this model, tools, equipment, technology, and environment exert physical demands on the worker, but they may also influence work organization. Organizational factors affect biomechanical strain either through physical demands or via psychosocial strain. The cognitive component is an important part in this model. Work organization, psychosocial strain, and individual factors have moderating roles: development of musculoskeletal symptoms is influenced by different contextual and experiential factors. The hypothesis examined in the kitchen ergonomics study was that by implementing the changes in tools, equipment, and technology, it would be possible to diminish physical demands and biomechanical strain at kitchen work, and occurrence of musculoskeletal disorders of the workers would be reduced.

2.1.1 Work-related physical risk factors for neck or neck/shoulder pain or disorders

Several studies have concluded that awkward neck or trunk postures are associated with neck pain or disorders (Ariëns et al. 2000, Hansson 2001a, Palmer and Smedley 2007, Côté et al. 2008). Other physical risk factors linked to these disorders have been repetitive work with arms (Palmer and Smedley 2007, Côté et al. 2008), use of hand force (Ariëns et al. 2000, Palmer and Smedley 2007), sedentary work (Ariëns et al. 2000, Côté et al. 2008), and working with elevated upper arms (Ariëns et al. 2000, Côté et al. 2008) (Appendix, Table 1).

There are very few previously published reviews related to shoulder pain or disorders. Van der Windt et al. (2000) concluded in their review that heavy physical work load, repetitive movements, and awkward postures were associated with shoulder pain. Styf (2001) reported that the risk factors for shoulder pain were highly repetitive, static work with the arms abducted or elevated. After those reviews, several original studies have emphasized especially the effects of combinations of two or more risk factors (Punnett et al. 2000, Frost et al. 2002, Miranda et al. 2008, Silverstein et al. 2008). In addition, lifting heavy weights (Harkness et al. 2003, Miranda et al. 2008), carrying (Harkness et al. 2003), pushing and pulling (Hoozemans et al. 2002a), as well as high force requirements in general have shown to be risk factors for shoulder pain (Appendix, Table 2).

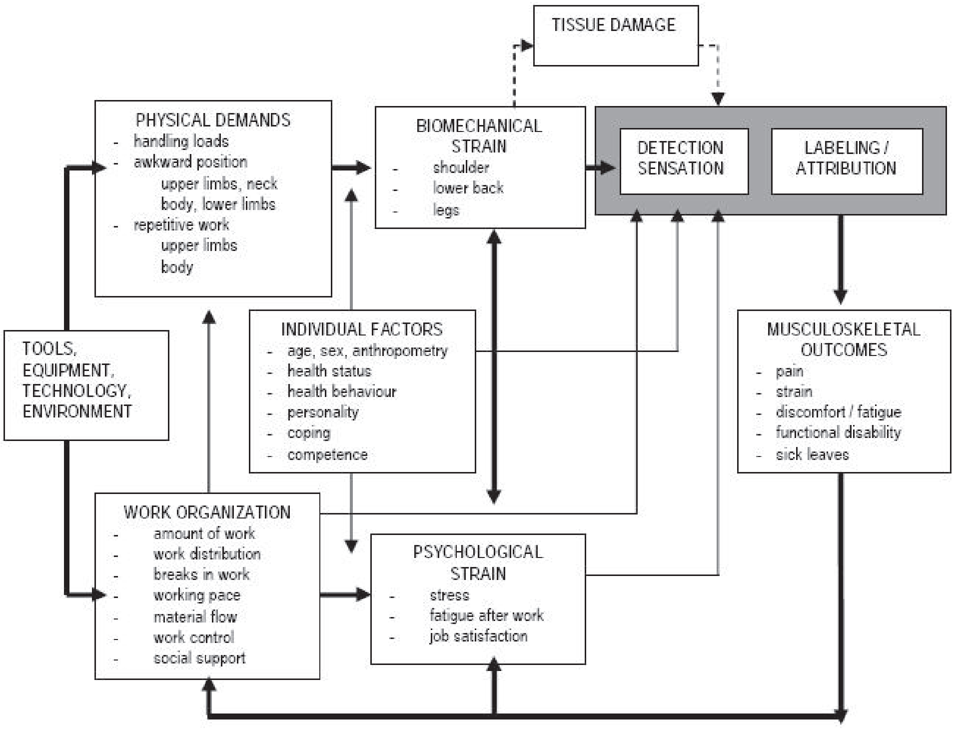

Figure 1. Conceptual model explaining the pathways leading to musculoskeletal disorders at kitchen work (adapted from Sauter and Swansson, 1996).

2.1.2 Work-related physical risk factors for elbow, wrist and hand pain or disorders

The most common disorders in the distal upper limb are the epicondylitis, hand/wrist tendinitis, and carpal tunnel syndrome. The reviews have concluded that highly repetitive work with the hands, use of high hand force, and especially the combination of these two factors increase the risks of these disorders. However, these conclusions should be interpreted with caution, because there are few high quality longitudinal studies (Vingård 2001a, Vingård 2001b, Palmer et al. 2007, van Rijn et al. 2009a, van Rijn et al. 2009b) (Appendix, Table 1).

2.1.3 Work-related physical risk factors for low back pain

According to several reviews manual material handling and frequent bending and twisting are risk factors for back disorders (Hoogendoorn et al. 1999, Kuiper et al. 1999, Hansson 2001b, Lötters et al. 2003) (Appendix, Table 1).

2.2 ASSESSMENT OF PHYSICAL LOAD FACTORS

2.2.1 General

Exposure assessment is a process, in which the magnitude, frequency, and duration of exposure is qualitatively or quantitatively estimated or measured. It is a major component of risk assessment (Last et al. 1995). Exposure assessment methods have often been categorized under three main headings: self-reports, observational methods, and technical measurements. Sometimes methods are used alone, but often two or more different methods (e.g. questionnaire and some observation method) are needed for collecting appropriate data. Table 1 describes advantages and challenges of the methods. The choice of the method depends on the required level of accuracy and precision, nature of the work tasks under study, feasibility of the method, and available resources for collecting and analyzing data (David 2005).

2.2.2 Self-reports of workers

Self-reports of the workers have been used especially in large surveys to evaluate physical exposures. The data are usually collected by questionnaires, diaries, checklists, or interviews. According to a review by Stock et al. (2005), most of the studies have been targeted to measure the presence or absence of an exposure, and provided only limited quantification of the intensity, duration or frequency of exposures.

The validity and reliability of self-reporting have been frequently questioned. Stock et al. (2005) concluded that repeatability has been good in questions concerning presence, duration, or frequency of general body postures (e.g. sitting or standing), but less satisfacory in questions involving postures of specific body parts (e.g. neck, shoulders, wrist, and trunk). The repeatability of questions on material handling has been better for broad categories than it has for more detailed questions. Questions on the level of physical effort at work showed good to excellent repeatability. The results of validity studies were varied. One reason may be the methodological limitations of the reference methods: repeatability and validity of the reference methods have only seldom been studied. In addition, there were other limitations to these studies, e.g. different sampling, small sample size, and the time interval between the questionnaire and reference method. Overall, questions on the level of the physical effort at work have corresponded well with the reference methods used (Stock et al. 2005, Barrero et al. 2009). In some studies, the presence of musculoskeletal symptoms has been found to have an effect on validity of the self-reporting. Generally, the workers with musculoskeletal complaints have reported higher exposure values than has been found by the reference method (Viikari-Juntura et al. 1996, Leijon et al. 2002, Balogh et al. 2004).

2.2.3 Observational methods

Observational methods are commonly used for assessing biomechanical exposures. The methods differ from each other in several ways. The assessment of physical exposure should include three dimensions of the load: level (amplitude), repetitiveness, and duration (Winkel and Mathiassen 1994). Typically, the available methods concentrate on the assessment of work postures, whereas other factors e.g. repetitiveness and duration of the posture or force have been taken into account less frequently (Li and Buckle 1999). Whole body observation methods (e.g. OWAS (Karhu et al. 1977), QEC (David et al. 2008), REBA (Hignett and McAtamney 2000)) generally assess the load in the low back, shoulders and lower extremities, whereas methods for upper extremity assessment (e.g. RULA (McAtamney and Corlett 1993), OCRA (Occhipinti 1998)) focus on shoulders, elbow and wrists. Several methods, especially different kind of checklists for assessing musculoskeletal hazards, are intended for observation at worksite. However, if work tasks are fast-changing and the number of observed factors is high, it is often more appropriate to record the work tasks on videotape and observe them afterwards in laboratory (Kilbom 1994, van der Beek and Frings-Dresen 1998, Spielholz et al. 2001). The sampling of the methods vary: sampling may be based on continuous observation for longer periods (PEO (Fransson-Hall et al.

1995), TRAC (Frings-Dresen and Kuijer 1995)), fixed time intervals (OWAS (Karhu et al. 1977), PATH (Buchholz et al. 1996)), or it may be focussed merely on "problematic situations" (QEC (David et al. 2008)).

In addition, the outputs of the methods differ. Some methods provide only descriptive profiles of the observed items. Since the risk factors co-occur and interact, in some methods, e.g. in QEC (David et al. 2008) and RULA (McAtamney and Corlett 1993), the risk factors are first observed separately and the exposure levels for different risk factors are subsequently combined to produce a final score.

When measuring exposures for epidemiological studies two approaches can be used: individual approach and group approach. In the individual approach, each worker is observed, whereas in the group approach some workers in predefined occupational groups are observed and the same exposure value is then given to all of the members of these groups. One prerequisite of the group approach is that enough workers need to be observed with a sufficient number of repetitions (Jansen and Burdorf 2003).

2.2.4 Technical measurements

Technical measurements, e.g electromyography (EMG), inclinometers, goniometers, and biomechanical measurements, are able to provide the most exact and accurate data about the physical load. Even though the feasibility of the methods in field studies has improved with the development of the measurement devices, they are rarely used in epidemiological studies due to the high costs and other limitations.

Table 1. Advantages and challenges of methods to assess physical load factors at work. (Burdorf et al. 1997, Juul-Kristensen et al. 1997, David 2005)

Method	Advantages	Challenges
Self-reports of workers • questionnaires • interviews • diaries • checklists • self-evaluation from video	• low costs • possibility to study large number of subjects • past and current exposure assessment possible • several kinds of data can be collected	• validity • repeatability • respondents' literacy, comprehension, and interpretation of questions can affect responding • recall / interview bias • gross categories
Observation methods • in the field • from video • from photographs	• moderate costs • practical in wide range of workplaces	• repeatability • validity • scoring systems are hypothetical • trained staff needed • sampling problems
Technical measurements • EMG • inclinometer • goniometer	• high validity • high repeatability	• high costs • time-consuming • highly trained and skilled staff needed • only limited set of body parts can be measured • sampling problems • only small number of workers can be measured • discomfort for workers • possible modifications in work behaviour due to wearing equipment or being observed • huge amount of data may be difficult to manage and interpret

2.2.5 Evaluation of the methods to assess physical exposures

There is no generally accepted framework for evaluating methods assessing physical exposures. However, acceptance of product or software has been studied and a similar approach could be adapted also in evaluating methods. According to Shackel (1991), acceptance of a product consists of three components: utility, usability and likeability, which have to be balanced in a trade-off against costs. Thus, in the selection of an observation method, the relevant aspects could be utility, usability, validity, repeatability, and costs.

Utility and usability of methods have only seldom been studied. Shackel (1991) defines utility as a capability of the product to correspond to the needs of the user. Usability means the user's ability to utilise the functionality in practice. Hence, the usability is not constant, but it varies depending on the users. Usability includes four parts: 1) effectiveness (speed and errors), 2) learnability (e.g. time to learn), 3) flexibility (e.g. in different contexts), and 4) attitude (levels of human costs, e.g. tiredness and frustration) (Shackel 1991). These aspects are relevant also when assessing utility and usability of the methods.

The possibility to obtain relevant data depends on the method's accuracy, and therefore the measurement error should be minimized. Measurement error consists of two parts: systematic error (also known as bias) and random error. Systematic error presents consistently in the same direction, and it impacts on the validity of the method. If the systematic error is low, the method is valid, and one is able to measure what is intended to be measured. In contrast, random error fluctuates non-systematically and it affects the repeatability of the method (Robson et al. 2001).

The *repeatability* of the method means that the results are coherent in repeated observations. Intra-observer-repeatability refers to the ability of the method to provide identical results during repeated observations of the same work situations by the same observer at different time points, whereas inter-observer-repeatability is the ability of the method to provide identical results when two or more observers observe the same work situation (Øvretveit 1998).

In the literature, *validity* is classified in different ways. Generally, at least the following three types of validity have been mentioned: criterion validity, content validity and construct validity (Last et al. 1995, Øvretveit 1998). The criterion validity consists of two parts: concurrent validity and predictive validity. Concurrent validity of the observation method has been assessed by comparing the results with those obtained using another, more valid, method, which has been regarded as a "golden standard". For example, the validity of the posture observation has been estimated using inclinometers or goniometers (Burdorf et al. 1992, Leskinen et al. 1997, Juul-Kristensen et al. 2001, Ketola et al. 2001). Predictive validity refers to the ability of the method to predict outcomes, for example musculoskeletal pain. Content validity is a subjective assessment of a group of reviewers with expert knowledge on the subject matter. The group assesses whether the method includes all aspects that should be included and does not include aspects that should not be considered. Construct validity refers to whether the method corresponds to theoretical concepts concerning the phenomenon under study. This can often be done only after years of experience by several users. *Sensitivity* refers to the probability that the observer finds a truly existing load factor, whereas *specificity* indicates that the observer can detect no load factor when it truly does not exist (Streiner and Norman 1995).

There are very few reviews which have evaluated the observational methods intended to assess the musculoskeletal load. Assessment of validity and repeatability of the methods was the target of two reviews. Denis et al. (2000) reviewed 38 methods, in which 55 % provided information on reliability. The observer's experience and training have an impact on the repeatability, though this was only rarely mentioned in the original reports. Internal validity (validity within the specific study) was also very seldom tested. The review points out the importance of problems in observations and emphasizes the need to define clearly formulated and supported observation procedures (Denis et al. 2000). In her review, Kilbom (1994) evaluated the usefulness of 19 observation methods, and made certain recommendations e.g. on building up categories, training in the method, and use of other sources in addition to observations. Reliability was tested in 58 % of those methods, and internal validity in 32 % of them. Juul-Kristensen et al. (1997) compared eight methods and noted that the methods have different classification criteria for postures, which hampers comparison of the results. Li and Buckle (1999) and David (2005) both listed 19 methods. However, no systematic searches in databases, in-depth analysis or comparison of methods were carried out. Dempsey et al. (2005) studied what types of methods the practitioners used, and tried to identify their reasons for the selection of the methods. The study included 13 observation based methods, in which those involving manual material handling (e.g. NIOSH lifting equation) were most commonly used. In addition to observational methods, several workload standards contain observational components (Fallentin et al. 2001a).

2.3 CONTROL OF PHYSICAL LOAD FACTORS

Ergonomic intervention consists of procedures targeted at the physical working environment, tools, materials, working techniques, or organization of work. Hence, it can, at least theoretically, be an effective way to prevent MSDs. Formerly interventions were targeted mainly at the micro level, i.e. on individual tasks, work stations, or equipment. Recently the context has been expanded and the target has enlarged to incorporate workplace policies and organizational design (macroergonomics) (Cole et al. 2003). However, these two levels are not mutually exclusive, and the best results can be attained by strengthening the relationship between macro- and microergonomics (Zink 2000).

2.3.1 Participatory ergonomic interventions

According to the definition devised by Wilson and Haines (1997), *participatory ergonomics* (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'. Thus, in this approach the workers or their representatives are the main actors in process of change. In addition to the workers, the successfulness of the project depends on the participation of other stakeholders. Strong support of the management is essential, but attention has to be paid also to the participation of other groups, such as health and safety personnel, designers, and technical staff (Vink et al. 2006).

The participatory approach has been shown to possess several advantages. First, the approach exploits the experience and knowledge of workers, which makes it possible to find out new targets for development and appropriate ways to solve them. Second, workers' involvement in the analysis, development, and implementation of the changes may enhance their commitment and improve their acceptance of changes. Third, the participatory process is often a learning experience for the participants. In order to help the workers to analyse and develop their work, their competence in ergonomics has to be enhanced. An important requirement for ergonomics competence is ergonomics literacy, which is composed of three parts: 1) ergonomics knowledge and skills, 2) ergonomic way of thinking, and 3) practical ergonomics capabilities. In addition, participation in the project may improve collaboration between workers and other stakeholders (e.g. management, technical stuff) (Haines and Wilson 1998, Karwowski 2005).

There is no single model or concept for participatory ergonomics; the most appropriate strategy has to be chosen to fit the individual situation (de Jong and Vink 2002, Haines et al. 2002). The basic phases in an intervention are problem identification, development of ideas and solutions, and implementation of the changes. In the problem identification phase, the tools may be accurate, such as direct measurements, or they may be less accurate, such as observational methods. However, in practice, the most common methods used are different check lists and questionnaires. In participatory ergonomic interventions, it is important to choose a method in which the workers will be active participants already during the problem identification phase (Zalk 2001, Vink et al. 2006).

The participatory approach has been used in several fields of working life, e.g. in manufacturing, construction, production and processing, services, transport, health care, military, and office work (Hignett et al. 2005, Rivilis et al. 2008). A review of 12 studies with the quality rating as 'medium' or higher found moderate evidence, that PE interventions have had a positive impact on MSD related symptoms. In addition, there is partial evidence for a positive impact in reducing MSD injuries, workers' compensation claims, and lost days from work or sickness absence due to MSD (Rivilis et al. 2008).

2.3.2 Evaluation of interventions

The main aim of an ergonomic intervention for the control MSDs is usually to reduce exposure which is expected to lead to better health. Hence, the first research question in intervention studies is whether or not the planned intervention was conducted as intended. The second question is related to the impact of effectiveness, i.e. whether the intervention (as implemented) led to the intended changes in exposure, and the third one, whether the changes in exposure had the intended effect on the study outcomes (Kristensen 2005).

According to reviews it does seem that the documentation and especially evaluation of intervention programmes have often been inadequate (Westgaard and Winkel 1997, Lincoln et al. 2000, van Poppel et al. 2004). The most obvious goal of the evaluation is often the effectiveness of the intervention. Goldenhar and Schulte (1994) evaluated the methodological quality of occupational intervention studies and stated that there was too little focus on the intervention process itself. Obviously, it is also important to evaluate the development and implementation of the interventions.

Need assessment research (also referred to as 'intervention development') tries to determine what kind of changes are needed and what are the best ways to achieve those changes. The knowledge, attitudes, and behaviour of the target population as well as the context in which the intervention will be conducted are important aspects to be defined when one is developing an intervention. The need assessment may often be complicated due to several factors: 1) there are often several needs, but resources are limited, 2) participants may have different needs, 3) participants may have different perceptions of the priority of the needs, 4) participants may have different perceptions of the strategies required for solving problems, and 5) collecting sufficient and meaningful data on the baseline situation may be challenging. Most needs are driven by values. In addition, different needs may compete with each other and therefore have to be prioritized (Goldenhar et al. 2001, Wilson and Haines 2001, Mathison 2005, Craig et al. 2008).

The process evaluation (also referred to as 'formative evaluation' or 'implementation assessment') examines the implementation, receipt, and setting of an intervention and it helps in the interpretation of the outcome results (Kristensen 2005). Recently, the importance of process evaluation has increased in conjunction with the complexity of interventions. The process evaluation can help explain negative, positive or insignificant results. In addition, information is needed in order to understand the relationships among selected intervention or program components, developing the processes, and for replicating effective interventions to other settings (Goldenhar et al. 2001, Linnan and Steckler 2002, Hulscher et al. 2003, Oakley et al. 2006).

However, there is a lack of consistent definitions for the key components of the process evaluation, nor is there a systematic procedure for planning and developing a process evaluation. Data on process evaluation can be both quantitative and qualitative, but very little is known about how appropriate the different methods are in different situations. Linnan and Steckler (2002) listed seven key process components: 1) context, 2) reach, 3) dose delivered, 4) dose received, 5) fidelity, 6) implementation, and 7) recruitment, of which the first component, 'context', is linked more to need assessment described earlier. They defined 'Reach' to refer the degree to which the intended audience will participate in an intervention, and it is often measured as the percentage of the participators that attend a given intervention. 'Dose delivered' is related to the program implementation. It refers to the amount of the intended intervention that is delivered (e.g. how many workshops were arranged), whereas 'dose received' assesses the commitment of participants to the intervention (e.g. how actively the participants used the materials or recommended resources). 'Fidelity' assesses whether the intervention was carried out according to the pre-specified plan. This data is often collected with questionnaires filled in by staff members, and therefore the problem is that the assessment will be subjective. 'Program implementation' combines data on reach, dose delivered, dose received, and fidelity. 'Recruitment', in the process evaluation focuses on examining the resources that were employed as well as reasons for nonparticipation (Linnan and Steckler 2002).

Intervention effectiveness evaluation (also referred to as 'impact evaluation, 'outcome evaluation' or 'summative evaluation') encompasses both the exposure change evaluation and the health outcome evaluation. In other words, it tries to respond to questions such as: What is the effect of the intervention on exposure at work or occupational disability? Did the workers' knowledge, attitude, or behaviour change due to the intervention (Goldenhar et al. 2001)?

In addition, Robson et al. (2001) distinguished three types of evaluation in relation to the costs of the intervention: *cost-outcome analysis* (compares health effects to net costs), *cost-effectiveness analysis* (examines both the costs and health outcomes of alternative intervention strategies), *and cost-benefit analysis* (compares all benefits to all costs).

The evaluation may be either internal or external. In an internal evaluation, participants evaluate the intervention themselves. The strength of an internal evaluation is that the participants know the context in which the intervention has been conducted. Its limitation is that the evaluation is not objective. In an external evaluation, some external evaluator performs the evaluation (Mathison 2005).

2.4 PROFESSIONAL KITCHEN WORK AS A RISK FOR MUSCULOSKELETAL DISORDERS

Professional kitchen workers work in municipal kitchens (e.g. in schools, kindergartens, hospitals, nursing homes, and geriatric service centres), and in the private sector (e.g. in restaurants). The profession is common: for example in Finland, kitchen workers comprise about 3% of the work force (Statistics Finland 2005). Even though kitchen workers have a high prevalence of MSDs and their work involves several physical and psychosocial risk factors for these disorders, very few studies have examined risk factors present in kitchen work or the musculoskeletal health of the kitchen workers. Kitchen work imposes dynamic and static loading on the entire musculoskeletal system. The physical exposures include awkward postures, manual material handling, and repetitive and forceful movements (Pekkarinen and Anttonen 1988, Perkiö-Mäkelä et al. 2006). Of the psychosocial factors, working under time pressure and low job control are characteristic to kitchen work (Perkiö-Mäkelä et al. 2006).

Kitchen workers have a high prevalence of disorders in the back, shoulders, and upper extremities (Huang et al. 1988, Ono et al. 1997, Ono et al. 1998, Haukka et al. 2006). In a study of workers in canteen kitchens, almost one in every three (30%) had a medically confirmed musculoskeletal disorder, and of these three out of four disorders were in the shoulders. Shorter workers experienced neck and shoulder complaints more often than their taller counterparts. The symptoms were assumed to be associated with the elevated position of the upper limbs due to too high working surfaces (Pekkarinen and Anttonen 1988). Huang et al. compared risk factors and musculoskeletal disorders in two different lunch centres. Shoulder pain was more prevalent in the kitchen with less automation (Huang et al. 1988). Ono et al. studied work-relatedness of low back pain and epicondylitis among nursery school cooks. In general, cooks had a higher prevalence of disorders and self estimated job stressors than the references. Low back pain was associated with the number of lunches to be prepared, age, body height, as well as psychosocial factors such as high work load and high job demands. Epicondylitis had a strong association with job title, and a weaker association with static work postures, repetitive movements and some psychosocial factors (Ono et al. 1997, Ono et al. 1998).

3 Theoretical framework of the study

The framework of this thesis (Fig. 2) is based on the conceptual model devised by Rivilis et al. (2008). The aim of the participatory ergonomic intervention study was to reduce musculoskeletal pain and trouble due to the pain by reducing physical exposures, by increasing workers' knowledge, by changing their attitudes and behaviour, and by conducting changes in the physical and psychosocial aspects of work in kitchens. Physical exposures, attitudes, behaviour, and level of ergonomic knowledge were targeted using a participatory approach. The comprehensive evaluation of participatory ergonomic intervention consisted of several parts: Need assessment, process evaluation, exposure change evaluation, health outcome evaluation, and economic evaluation. The last of these topics was not included in this thesis. In the need assessment phase, basic information is collected for the planning of the intervention process. However, when planning the process, also the facilitators and barriers (e.g. resources) to the process have be to taken into account. One important facet of the PE process is learning done by the participants since this helps both in the identifying the problems and in developing solutions. The intermediate aims in the process are reduction of exposures and promotion of positive factors (e.g. support from management) as well as changes in knowledge, attitudes, and behaviours of the participants. These outcomes are supposed to lead to a reduction of musculoskeletal pain and trouble due to the pain. It is essential to conduct an assessment of physical exposure at baseline in order to identify the needs for the intervention and after the intervention to evaluate changes in exposures. In this thesis, Studies I and II concentrated on exposure assessment methods and Study III on evaluation of the intervention process. Study IV assessed the effects of changes of exposure on shoulder pain and trouble due to the pain, when two different methods were used to assess exposure.

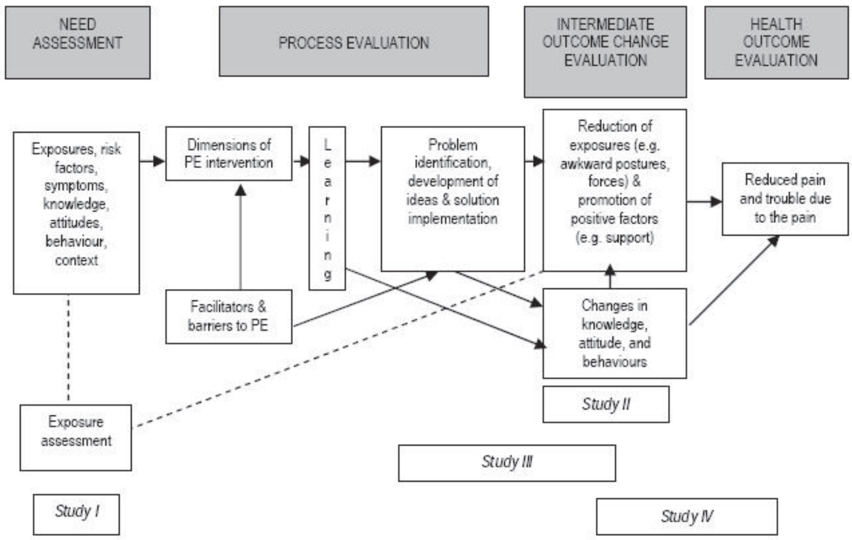

Figure 2. Conceptual model of pathways of change in participatory intervention and corresponding evaluations (adapted from Rivilis et al., 2008).

4 Aims of the study

The general aim of this thesis was to evaluate different methods for assessing musculoskeletal load as well as the feasibility and the effects of a participatory ergonomic intervention in kitchen work.

The specific aims of the studies were:

1. To systematically evaluate published and commonly used observation methods for assessing biomechanical exposures from the perspective of different users (Study I).
2. To investigate the inter-observer repeatability, validity, and usability of a new video-based observation method developed for the intervention study (Study II).
3. To evaluate a participatory ergonomic intervention process in kitchen work (Study III).
4. To study the association of self-reported and observed physical work load with future shoulder pain and trouble due to the pain (Study IV).

5 Materials and methods

5.1 GENERAL DESCRIPTION OF THE THESIS

Study I is a literature review that evaluates the observational methods measuring physical exposures relevant to the musculoskeletal system. Studies II, III and IV are based on a randomized controlled intervention trial carried out in municipal kitchens in 2002-2005. The hypothesis of this trial was that MSDs could be prevented by developing the ergonomics and optimizing the musculoskeletal and mental load at work.

The study was carried out in 119 municipal kitchens with 504 workers in four cities. Kitchens with at least three full-time workers were eligible for the study. In all but one of the kitchens, meals were both prepared and served. They were located in schools (n=85), kindergartens (n=21), nursing homes (n=6) and service centres (n= 6). One kitchen was a large central kitchen where meals were prepared and then sent to other kitchens or directly to the customers.

The study was carried out in a series of an average eight kitchens (n=16 series), which entered the study sequentially in time. Half of the kitchens were randomized to the intervention and half to the control group. Both groups in each series proceeded in the same phase of time. Four research teams, composed of two researchers each, implemented the field phase. The intervention group (n=59 kitchens) developed ergonomics in their work during the 11-14 months intervention phase, whereas the control group (n=60 kitchens) continued their work as usual.

Exposure assessment was needed to identify the targets of the intervention and to measure possible changes in physical work load as a result of the intervention. In each kitchen, the risk factors for musculoskeletal disorders were observed at baseline during one day. After the intervention phase, all intervention kitchens and one out every four of the control kitchens were observed. During the intervention phase, a total of 402 changes were implemented. In order to assess the possible changes in physical workload in "pre-post-intervention situations", visible changes were recorded on video.

Work tasks are rather similar across professional kitchens, but especially time used for each task varies e.g. depending on the type of the kitchen. In kitchen work, eight main work tasks can be distinguished: 1) receiving and storing of incoming raw material 2) pre-preparation, 3) cooking and baking, 4) packing food to be delivered to customers, 5) setting out and serving food, 6) dishwashing, 7) cleaning and maintenance of kitchens and equipment, and 8) office work. The duration of the work tasks can vary from some minutes (e.g. storing raw material) to several hours (e.g. dishwashing). Particularly in small kitchens, a typical feature of the work is that all workers perform each work task, and that several work tasks are being carried out in parallel.

The characteristics of kitchen work set challenges for the assessment of physical exposures. One challenge is the substantial variability of the work during each day, between days (because of the menu of the day) and between workers. In addition, kitchen work imposes loads on the entire musculoskeletal system, there are fairly quick changes between tasks and working postures, and some tasks are carried out in parallel. Another challenge was our limited resources. Hence in order to target these interventions, it was necessary to develop an observation method that could 1) assess the loading on the entire body, 2) be suitable for variable, fast-changing and dynamic tasks, 3) take into account of the magnitude, repetition, and duration of exposure, and 4) not be too demanding for the observers, who had to observe work tasks over a full working day. Demands to the method for assessing possible changes in biomechanical exposures before and after the intervention were that it could 1) assess the loading on the entire body, 2) be suitable for variable, fast-changing and dynamic tasks, 3) take into account the magnitude, repetition, and duration of exposure, 4) be suitable for used in observation from videos, and 5) be accurate enough to detect possible changes as a result of the intervention. Since there were no suitable published methods for our purposes, two new observation methods were developed (expert observation method, Study IV, and a video-based observation method, Study II). The literature on previous observation methods and risk factors of MSDs was used in the development of these methods. In addition, the workers were inquired with questionnaires about the strenuousness of the work tasks at baseline and after the intervention phase (Study IV).

The designs, methods, time points, informants and objects in studies II-IV are presented in Table 2, and described more broadly in text.

Table 2. Summary of data collection in Studies II-IV.

Study	Design	Method	Time point	Informants and objects
II	Method description and evaluation	• Video-observation method (KILA)	Before and after intervention	Researchers (two observer pairs); 50 pre-post-intervention situations
		• Expert assessment of the changes	Before and after intervention	Researchers (n=8)
III	Pre-post intervention	• Questionnaire		
		○ Successfulness	After intervention	Workers collectively in each kitchen (n=57)
		○ Ergonomic knowledge	Before and after intervention	Workers (n=70)
		○ Expectations and perceived effects	Before and after intervention	Workers (n=101)
IV	Prospective study	• Focus group interviews	After intervention	Representatives of workers (n=6) and management (n=6)
		• Research diaries	During the intervention phase	Researchers (n=8)
		• Questionnaire		
		○ Strenuousness of work tasks	Before and after intervention	Workers (n=376)
		○ Health outcomes	Before and after intervention	Workers (n=376)
		• Expert observation method	Before and after intervention	Researchers; 69 kitchens with 183 workers

5.2 REVIEW OF OBSERVATION METHODS (STUDY I)

The aim of Study I was to review the published observation methods targeted at assessing biomechanical exposures on the musculoskeletal system, and to evaluate them from the perspective of different users' needs.

5.2.1 Search and selection of reference literature and observation methods

The literature search was conducted in four electronic databases: PubMed, Embase, CISDOC, and ScienceDirect. In addition Google and Google Scholar were used to identify sources via the internet. The primary search with the search terms was described in original publication I. An additional search was performed using the names of the methods and using a snowball method e.g. viewing 'related articles' of the key references. The searches covered material from 1965 to September 2008. The title and abstract were first screened by one researcher. After this screening, full texts of 580 eligible papers were collated by two researchers. The inclusion criteria of the methods were 1) that the tool is primarily based on a systematic observation of work, 2) that the observation target is the human body, especially the musculoskeletal system, and 3) the method is described in sufficient clarity.

5.2.2 Development of the framework for evaluation

Even though several reviews on observation methods for the assessment of physical work load have been published previously, there is no generally accepted way to evaluate the methods. For this study, the structure and contents for the evaluation were developed in meetings of the research team. The evaluation included questions on validity (concurrent and predictive validity) and repeatability of the method. In addition, the tool's strengths and limitations as well as potential user groups were evaluated.

5.2.3 Evaluation

Two researchers from the group of authors read the selected publications, and independently filled in the basic information into the evaluation forms. Then they discussed and reached a consensus of the basic description of the methods to be written in the forms in the documentation. Based on this documentation as well as the original reports, at least two evaluators evaluated the methods blinded to each other. In addition, the third member of the group evaluated 14 of the methods. Discrepancies were resolved by discussions amongst the evaluators in order to establish a consensus.

5.3 DEVELOPMENT AND EVALUATION OF A VIDEO-BASED OBSERVATION METHOD (STUDY II)

In the kitchen ergonomics study, a total of 50 changes were recorded on video before the intervention phase as well as after the intervention. In Study II, a new video-based observation method (KILA = Kitchen Intervention Work Load Assessment) for assessing changes in work load was developed and described. In addition, aspects of repeatability, validity, and usability of the method were evaluated.

5.3.1 Description of the method

The work tasks were observed in real time from the video in the laboratory. The assessment of the loading on the low back, shoulders, and wrists and hands was based on postures or grips, time aspects (duration and frequency), and force requirements. The cut-off limits for rating categories were chosen on the basis of the previous literature. The combination of the main posture or grip and its duration and frequency were ranked on a scale of seven categories. For shoulders and hands, both sides were assessed separately. The force requirements were rated into 4 or 5 classes by the weight handled or the force needed. (Table 3)

5.3.2 Assessment of the inter-observer repeatability, validity, and usability of the method

Because all studied work tasks (n=50) were recorded on the video before and after the intervention, and some work tasks with different sub-tasks were divided into shorter sub-tasks, a total of 117 clips were analyzed. The four observers (A, B, C, D) comprised two observer pairs: A&B observed 24 situations (=66 clips) and observer pair C&D 26 situations (=51 clips) (Table 4). Before the observations, they studied the written guide, and practiced using the method during a 7-hour training session. At first each observer conducted the assessment individually without discussing it with the partner. The clips were shown to them in a random order. Each clip was shown three times: first they assessed the low back, in the first replay they evaluated the shoulders, and in the second replay they focussed on the hands. After the individual assessment of each task, the observers made a consensus assessment. When they justified their views, they also reported orally the problems they had encountered during the assessment. The discussions were recorded on a minidisk.

Table 3. The basis for classification criteria for the assessment of postures and force requirements

	Low back	Shoulders	Hands/wrists
Posture	• neutral • flexion <20˚, 20-60˚ or >60˚ • twist/lateral bend ≤20˚ or >20˚	Angle between the trunk and upper arm • ≤20˚ • >20˚, but <45˚ • 45-90˚ • >90˚	• no grip or very light grip • power grip • narrow grip (e.g. pinch grip) or extensive grip • double grip (A precision grip in the radial fingers combined with a simultaneous power grip in the ulnar fingers)
Time (frequency and duration)	• occasional • repetitive/continuous	• occasional • repetitive/continuous	• occasional • repetitive/continuous
Weights handled / force needed	• <1 kg • ≥1 kg, but <5 kg • ≥5 kg, but <10 kg • ≥10 kg, but <20 kg • ≥20 kg.	• no load • ≤½ kg • >½ kg, but ≤4 kg • >4 kg, but ≤10 kg • >10 kg.	• light (e.g. sorting cold cuts) • somewhat heavy (e.g. stirring soup) • heavy (e.g. scooping food) • extremely heavy (e.g. lifting a sack ≥ 20 kg)

Table 4. Observed changes (n=50) by tasks and observer pairs

Task	A&B	C&D	Total
Receiving and storing of incoming raw material	-	2	2
Pre-preparation	1	1	2
Cooking and baking	3	4	7
Setting out and serving food	8	6	14
Packing food to be delivered to customers	3	1	4
Dish washing	6	4	10
Cleaning and maintenance of kitchens and equipment	3	8	11
Total	24	26	50

Inter-observer repeatability was studied by comparing the individual assessments of two observers. *Content validity* of the method was described by the distributions of the consensus assessments over the rating scales and by comparing the ratings between the situations before and after the intervention. During the intervention phase, the experts in ergonomics made assessments of the effects of the intervention on the loading of the low back, shoulders, and hands and wrists using a 7-point rating scale (-3 = highly increased loading, 0 = no effect, 3 = highly reduced loading). *Concurrent validity* of the KILA method was described by comparing the direction of the changes with the expert assessment. Expert assessments were available in 82% of the changes observed with the KILA. The *usability* of the method was studied by collecting data on difficulties encountered during the observations.

5.4 EVALUATION OF INTERVENTION PROCESS (STUDY III)

The aim of Study III was to evaluate the feasibility of the intervention process and its effects on workers' knowledge and awareness in ergonomics as well as their expectations and perceived effects on physical workload, ergonomics, and musculoskeletal health.

5.4.1 Theoretical basis for the intervention

The theoretical basis of the intervention was the hypothesis that by optimizing the biomechanical and psychosocial workload, the health of the musculoskeletal system could be maintained or promoted. The intervention was conducted using a participatory approach, which has previously been used in a study among kitchen workers (Hopsu et al. 2003). The framework of the intervention was based on the model developed and used in a project involving paper industry workers in the Finnish Institute of Occupational Health (Leppänen 2001). It was modified by experienced researchers so as to be suitable in the context of kitchen work. The aims of the intervention were 1) to increase the workers' ergonomics literacy (i.e. to increase the workers' knowledge and awareness of ergonomics in their work, and to encourage workers to be active participants in developing ergonomics), and 2) to implement improvements in kitchen ergonomics.

5.4.2 Description of the intervention process

The used model was based on learning of the participants. There were two levels in the learning process: First, the workers were taught basic knowledge in ergonomics, and some of the principles were then practiced. Second, the attempt was to improve communication between the workers within their own kitchen and with other kitchens as well as also between workers, management and technical personnel in sharing knowledge and experience. The teaching methods were lectures, practical training, interactive discussions, seeing, and learning by doing. The workers were the main actors in the intervention: they analyzed their work tasks, identified problems and generated solutions. The implementation of the changes was conducted by the workers, middle management and technical staff together. The role of the ergonomist was to initiate and guide the process, train the participants, and be available for consultation.

The intervention phase composed of two parts. In the beginning of a 2-month pre-implementation phase, the management and workers were informed about the study and an informed consent to participate was obtained from each worker. During this phase, also two 5-hour workshops were arranged in which all of the workers from three to five kitchens participated. In addition, the foodservice management and technical personnel were encouraged to participate in these workshops. In the first workshop, the workers started to analyze their work tasks with the help of the ergonomist. In this workshop, the researchers presented the results of questionnaires on perceived strenuousness of the work tasks as well as photographs of the most loading tasks. The participants used the problem identification grids developed for the study to analyze the work tasks and to determine the possible reasons for musculoskeletal load in each task. After the first workshop, the workers continued to analyze the tasks. In the second workshop, held one month later, they selected the first targets for development and planned the details of the implementation.

During the 9-12-month implementation phase, the ergonomist trained the workers in ergonomics (lectures and practical training) in six 3-hour workshops that rotated through the series of four kitchens. Each workshop had a specific theme. Five of them were targeted mainly at physical ergonomics with titles: 'The body as a tool', 'Working postures and workplace', 'Manual materials handling', 'Repetitive work', and 'Work environment and safety', and one at organisational ergonomics: 'Time pressure at work'. An important aspect of the workshops was discussion progress being made and further actions of the ongoing development. The workers also evaluated the implemented changes and tried to solve possible problems together.

Good practices were gathered into an idea folder available for all participating workers. In addition, the development was supported by extra visits to the kitchens by an ergonomist, and meetings with the management and collaborators if needed. The kitchens did not have extra funding to undertake ergonomic changes.

5.4.3 Evaluation of the intervention process

The study sample consisted of 59 intervention kitchens with 263 workers, of which 227 (86%) worked in the same kitchen throughout the intervention phase. The methods to assess feasibility and effects of the intervention are described in Table 5.

Feasibility of the intervention process

Information on success of the intervention process was collected with a questionnaire, filled in collectively by the workers in each kitchen. The satisfaction with the arrangements of the project, flow of information, implemented changes, and support from the management was assessed using a five-point scale. In addition, in two cities, the workers' experiences of the process were collected through semi-structured focus group interviews. Both groups consisted of three worker and three management representatives. The interviews included a total of ten questions, of which eight dealt with feasibility. In addition, research diaries were utilized to assess the feasibility of the process. They contained information on the visits made to the kitchens, meetings with collaborative partners, participation rates, and time used for the project.

Effects of the intervention

The effects of the intervention were evaluated based on the information on the ergonomic knowledge of the workers (questionnaire, focus group interviews), attitudes (focus group interviews), implemented changes (research diaries, questionnaire), and perceived effects on work load and musculoskeletal health (questionnaire, focus group interviews). The questionnaire surveys related to ergonomic knowledge and expectations were carried out in two cities before and after the intervention. The questionnaire on ergonomic knowledge included 10 statements on the topics discussed in the workshops. Each worker answered individually the statements using a score from one to seven (1 = 'totally agree' to 7 = 'totally disagree'). Data on workers' expectations regarding the effects of the intervention before the intervention and their assessments after the intervention were collected with three questions. Each worker filled in the questionnaires individually using a five-point scale. In focus group interviews, two topics were linked to the effects of the intervention.

Table 5. Methods to assess feasibility and effects of the intervention

Assessed factor	Research diaries	Questionnaire on successfulness of intervention	Questionnaire on ergonomic knowledge	Questionnaire on expectations and perceived effects	Focus group interviews
		Data collection method			
Feasibility					
Intervention process					
• Workshops		x			x
• Visits to other kitchens					x
• Teamwork with participatory approach		x			x
• Duration of the intervention phase	x				x
Resources and support					
• Personnel resources	x				x
• Empowerment of workers					x
• Financial resources for acquisition	x				x
• Support from management	x	x			x
• Support from ergonomist	x	x			x
Effects					
Ergonomic knowledge			x		x
Attitude and way of functioning					x
Implemented changes	x			x	
Physical loading				x	x
Psychosocial work characteristics		x			x
Musculoskeletal health				x	x

5.5 ASSOCIATION BETWEEN CHANGES IN WORK LOAD AND FUTURE SHOULDER SYMPTOMS (STUDY IV)

The aim of Study IV was to examine the effect of the changes in perceived and observed workload on future shoulder complaints. Changes in perceived workload were studied among 376 female kitchen workers. Expert observations of shoulder loading exposure were performed in 69 kitchens at baseline and at the end of the one year follow-up. Altogether 183 workers were employed in these kitchens throughout the follow-up.

5.5.1 Health outcomes

Data on shoulder pain and trouble due to the pain were collected both at baseline and follow-up with questionnaires. Shoulder pain was assessed with the question: "Have you had pain in your right (left) shoulder during the past three months? (yes/no)". If the answer was 'yes', the worker was asked to assess how much shoulder pain was bothering her/him using a seven-point scale: 'not at all', 'very little', 'little', 'moderately', 'quite much', 'much' and 'very much'. The variable was further dichotomized so that 'not at all' or 'very little' formed the reference class and the rest of the classes were combined. The outcomes of this study were pain in either one or both shoulders as well as trouble due to the shoulder pain at follow-up.

5.5.2 Determinants

Data on physical exposures were collected with questionnaires and by observations in kitchens.

Physical strenuousness

The workers were asked to rate the physical strenuousness of the work tasks they have done during the previous week at baseline and after the intervention phase. A seven-unit scale was used for the rating (1 = 'not at all strenuous' to 7 = 'very strenuous'). To assess the changes in strenuousness the follow-up value was compared to the baseline value. At least decrease of two units during the follow-up in the strenuousness of a work task was required for it to be categorized as 'decreased perceived work load'. Those with no or a minor change (or increase) in the strenuousness formed the reference group. If the workers did not perform a work task during the previous week they were asked to mark 'zero' for that task and the information was not used in the analyses.

Observed physical exposures

Physical exposures in each work task were observed by experts using a method developed for this study (Stenholm 2003). Eight generic risk factors for work-related musculoskeletal disorders were observed: standing, awkward trunk postures, kneeling, lifting, working with elevated upper arm, forceful gripping, deviated wrist postures, and repetitive hand actions. A value ranging from 1 to 3 (1 = little or not at all exposure; 2 = moderate exposure; and 3 = high exposure) was given to the exposure based on a combination of the magnitude, duration and frequency. The current literature and general standards were utilized in the formation of the classification (Fransson-Hall et al. 1995, Hignett and McAtamney 2000, Ketola et al. 2001, Washington State Deptartment of Labor and Industries 2003). In the analysis, focus was placed on the most well-established physical risk factors for the shoulder problems, i.e. lifting and working with elevated upper arm. Inter-observer repeatability of the method was moderate to excellent (κ_w = 0.4-1.0) for lifting, and moderate for elevation of upper arm (κ_w = 0.4) (Fleiss 1973, Stenholm 2003).

The observations were performed for one full work day by two researchers at baseline and by one researcher at the follow-up. The observer chose randomly a worker performing any work task in the kitchen. In the situation where some of the seven main work tasks were observed more than once, the means of the values were calculated, and classified into the three categories. In municipal kitchen work, all of the workers in kitchen will participate in almost all work tasks. Therefore, the same observed exposure value was imputed to all workers in the same kitchen. In the analysis, a decrease of one unit or more during the follow-up was categorized as 'decreased observed work load'. Those with no change or increase in the observed exposure level were treated as the reference group.

5.5.3 Covariates

The variables included in the study as covariates were chosen based on the literature: age, body mass index (BMI, kg/m^2, based on self-reported weight and height), leisure-time exercise, current smoking, self-reported diabetes, job demands, and job control. Their role as potential confounders as well as effect modifiers was investigated.

5.6 DATA ANALYSIS

5.6.1 Study II

Inter-observer repeatability was assessed by computing the proportion of agreement and weighted kappa values (κ_w) with their 95% confidence intervals (Crewson 2001). The weighted kappa takes into account the magnitude of the disagreement among observers. The classification of weighted kappa values was performed according to Fleiss (1973): $\kappa_w < 0.4$ was regarded as poor, from 0.4 to 0.75 as moderate to good, and > 0.75 as excellent. Frequencies and proportions were used to describe the distributions of the consensus assessments over the rating scales, before and after the changes, and in the comparison of the observations with the 'expert assessments'.

5.6.2 Study III

Descriptive statistics were computed for the turnover of staff in kitchens, participation rates in the workshops, time needed for development, and workers' opinions on the success and effects of the process. The general knowledge level of ergonomics was assessed by calculating the mean score for the ten statements on ergonomics: the higher the mean score, the better the knowledge. The overall change in the general knowledge of ergonomics was analyzed using the paired *t*-test and mixed models. The difference between the expectations before and the perceived effects after the intervention was analyzed with the Wilcoxon signed rank test. The recordings of focus group interviews were studied and the identified emerging themes were related to feasibility and effects.

5.6.3 Study IV

Risk of reporting shoulder symptoms (pain and trouble due to pain) at follow-up related to the changes in the work load was estimated using logistic regression with odds ratios (OR) and 95% confidence intervals (95% CI). First, the 'crude' associations (adjusted only for baseline pain or trouble) were estimated. The selection of the potential confounders was determined for each variable separately. All models were adjusted for shoulder pain (or trouble) at baseline, and in the final model, also for age and the group status (intervention or control group). Interactions between the main determinants and covariates were tested, but no statistically significant interactions at the p-value level of

0.05 were found. All statistical analyses were performed using the SAS version 9.1 (SAS Institute Inc. 2004).

6 Results

6.1 EVALUATION OF OBSERVATION METHODS TO ASSESS PHYSICAL EXPOSURE

6.1.1 Evaluation of available observation methods (Study I)

A total of 30 observational workload assessment methods were identified in the literature search. The methods were classified into three groups according to the main focus of the method: general workload, upper limb activities, and manual material handling. The methods are briefly described in original publication I which has a full list of references. In addition, detailed information of the methods can be found at a website associated with the project (Takala et al. 2010). The evaluated methods are listed in Table 6 and the basic characteristics of the methods in Table 7. Sixteen of thirty methods considered all three dimensions of physical load (posture/force, duration, and frequency) (Table 7). Eleven methods presented no detailed criteria for observation. The prevailing practice using the methods with criteria was to observe most common and/or most loading postures or tasks.

Table 6. Evaluated methods, years of first publication, and reference

Method	Year of first publication	Reference
General methods		
Ovako working posture assessment system (OWAS)	1973	(Karhu et al. 1977)
Arbeitswissenschaftlihes erhebungsverfahren zur tätigkeitsanalyse (AET)	1979	(Landau et al. 1999)
Posture targeting	1979	(Corlett et al. 1979)
Ergonomic analysis (ERGAN, formerly ARBAN)	1982	(Holzmann 1982)
Task recording and analysis on computer (TRAC)	1992	(Frings-Dresen and Kuijer 1995)
Portable ergonomic observation (PEO)	1994	(Fransson-Hall et al. 1995)
Hands relative to the body (HARBO)	1995	(Wiktorin et al. 1995)
Plan för identifiering av belastingsfaktorer (PLIBEL)	1995	(Kemmlert 2005)
Posture, activity, tools, and handling (PATH)	1996	(Buchholz et al. 1996)
Quick exposure check (QEC)	1999	(David et al. 2008)
Rapid entire body assessment (REBA)	2000	(McAtamney and Hignett 2005)
Washington State ergonomic checklists	2000	(Washington State Department of Labor and Industries 2003)
Video- och datorbaserad arbetsanalys (VIDAR)	2000	(Forsman et al. 2003)
Postural loading on the upper-body assessment (LUBA)	2001	(Kee and Karwowski 2001)
Chung's postural workload evaluation	2002	(Chung et al. 2005)
Methods assessing workload on upper limbs		
Health and Safety Executive (HSE) upper-limb risk assessment method	1990	(Health and Safety Executives 2007)
Stetson's checklist	1991	(Stetson et al. 1991)
Rapid upper-limb assessment (RULA)	1993	(McAtamney and Corlett 2005)
Keyserling's cumulative trauma checklist	1993	(Keyserling et al. 1993)
Strain index	1995	(Moore and Vos 2005)
Occupational repetitive actions (OCRA)	1996	(Occhipinti and Colombini 2005)
American Conference of Governmental Industrial Hygienists' hand activity level (ACGIH HAL)	1997	(Armstrong 2006)
Washington State ergonomic checklist	2000	(Washington State Department of Labor and Industries 2003)
Ketola's upper limb expert tool	2001	(Ketola et al. 2001)

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Table 6 continued

Method	Year of first publication	Reference
Methods assessing mainly MMH		
NIOSH Lifting Equation	1981 (revised 1991)	(Waters 2006)
Arbouw	1997	(Arbouw Foundation 1997)
Washington State ergonomic checklists	2000	(Washington State Department of Labor and Industries 2003)
New Zealand code for material handling (NZ Code for MH)	2001	(Department of Labour Te Tar Mahi 2001)
Manual handling assessment charts (MAC)	2002	(Monnington et al. 2002)
Manual tasks risk assessment (ManTRA)	2004	(Burgess-Limerick et al. 2000-2004)
American Conference of Governmental Industrial Hygienists lifting threshold limit value (ACGIH Lifting TLV)	2004	(Marras and Hamrick 2006)
Back-exposure sampling tool (BackEST)	2008	(Village et al. 2009)

Of the 30 methods, 19 had been compared with other methods, e.g. technical measurements, expert assessments from video recordings or other observational methods (Table 8). Concurrent validity of eight methods — BackEST (Village et al. 2009), HARBO (Wiktorin et al. 1995), Ketola's upper limb expert tool (Ketola et al. 2001), OWAS (Burdorf et al. 1992), PATH (Paquet et al. 2001), PEO (Karlqvist et al. 1994, Leskinen et al. 1997), RULA (Fountain 2003), and TRAC (DeLooze et al. 1994) — was studied either entirely or partly (e.g. validity of back postures) using technical measurements. The study design of the validation trials varied from laboratory simulations of stereotypic tasks with accurate measures to observations at workplace.

Altogether 10 methods have shown an association with MSDs in cross-sectional studies. Two of those methods — Strain index (Knox and Moore 2001) and ACGIH HAL (Gell et al. 2005, Werner et al. 2005a, Werner et al. 2005b, Werner et al. 2005c, Werner et al. 2005e, Violante et al. 2007) — had also shown associations with MSDs in longitudinal studies.

Table 7. Description of observational methods

Method	Exposures and dimensions *	Metrics	Observation strategy	Mode of recording **
General methods				
OWAS	P, F	Frequency of items	Time sampling	PP, C
AET	P, F, Fr, Vib	Profile of items	No detailed rules	PP
Posture targeting	P	Frequency of postures	No detailed rules	PP
ERGAN (Arban)	-	Borg RPE scale	No detailed rules	V, C
TRAC	P, F, D, Fr	Distribution /duration of observed items	Time sampling / continuous observation	C
PEO	P, F, D, Fr, M	Start/end of postures	Continuous observ.	V, C
HARBO	P	Start/end of postures	Continuous observ.	V, C
PLIBEL	P, F, Fr, M	'Yes/No' answers. Profile of items	Selection by general knowledge of work and observations	PP
PATH	P, F, activity	Time spent in postures	Time sampling	PP, (V), C
QEC	P, F, D, Fr, M	Sum score of weighted items	'Worst case' of the task	PP
REBA	P, F	Sum score of weighted items	Most common/ prolonged/ loaded post.	PP
Washington State ergonomic checklists	P, F, D, Fr, M, Vib	'Yes/No' answers	Screening for tasks that are regular in work	PP
VIDAR	P, F, D, Fr, M	Borg RPE scale	By worker's needs	V, C
LUBA	P	Posture discomfort score	Most common / loaded postures	PP, V
Chung's postural workload evaluation	P	Posture discomfort score	No detailed rules	V, C

P= Posture, F=Force, D= Duration, Fr= Frequency of actions, M=movements, Vib=vibration, PP=Pen and paper, C= computerized, V= Video

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Table 7 continued

Method	Exposures and dimensions *	Metrics	Observation strategy	Mode of recording **
Methods assessing workload on upper limbs				
HSE UL	P, F, D, Fr, Vib	'Yes/no' answers	Tasks involving high repetition/ low variety	PP
Stetson's checklist	P, F, D, Fr	Frequency of items by their duration	No detailed rules	PP
RULA	P, F, Static action	Sum score of weighted items	No detailed rules	PP , V
Keyserling's Cumulative trauma checklist	P, F, D, Fr, Vib	Sum score of positive findings	Screening of job with questions put to the worker	PP
Strain index	P, F, D, Fr	Multiplied score; risk index	No detailed rules	PP
OCRA	P, F, D, Fr, Vib	Sum score of weighted items; risk index	Assessment of repetitive action incl. in profile of work	PP
ACGIH HAL	M, F	Hand activity and force requirement on VAS	"Typical activity"	PP, (V)
Washington State ergonomic checklist	P, F, D, Fr, Vib	'Yes/No' answers questions combining risk factors	Items selected by caution zone checklist	PP
Ketola's upper limb expert tool	P, F, D, Fr, Vib	'Yes/No' answers; profile of items	No detailed rules	PP
Methods assessing mainly MMH				
NIOSH Lifting Equation,	P, F, D, Fr	Multiplied score; risk index	No detailed rules	PP , C
Arbouw	P, F, D, Fr	3 levels of risk tables	No detailed rules	PP
Washington State ergonomic checklists	P, F, D, Fr	Lifting limit computed as multiplied score	Worst and most common lifts	PP
NZ Code for MH	P, F, D, Fr	Sum score of weighted items indicating risk	Flowchart; tasks incl. hazardous MMH	PP
MAC	P, F, Fr	Item profile; Sum score indicating risk	Selection by general knowledge of work	PP , (V)
ManTRA	P, F, D, Fr, Vib	Sum score of risk	Rules stated in Queensland manual tasks advisory stand.	PP
ACGIH Lifting TLV	P, F, D, Fr	Hazardous lifting TLV	No detailed rules	PP
BackEST	P, F, Vib	Frequency of items	Time sampling	PP

P= Posture, F=Force, D= Duration, Fr= Frequency of actions, M=movements, Vib=vibration, PP=Pen and paper, C= computerized, V= Vide

Table 8. Validity and repeatability of observational method

Method	Correspondence with 'valid' reference	Association with MSDs*	Intra-observer repeatability	Inter-observer repeatability
Methods assessing general workload				
OWAS	Moderate (discomfort, tech. measures)	X	Good	Good
AET	-	-	-	-
Posture targeting	-	-	-	-
ERGAN (Arban)	-	-	-	-
TRAC	Moderate (tech. measures)	X	-	Moderate-good
PEO	Moderate (video, tech. measures)	X	Good	Moderate-good
HARBO	Moderate (technical measures)	-	-	Good
PLIBEL	Moderate (AET)	-	-	Moderate
PATH	Moderate-good (video, tech. measures)	-	Moderate-good	Moderate-good
QEC	Good (video, tech. measures)	X	Moderate	Moderate
REBA	Moderate (OWAS)	-	-	Low-moderate
Washington State ergonomic checklists	Moderate	X	-	Moderate
VIDAR	-	-	-	-
LUBA	-	-	-	-
Chung's postural workload evaluation	-	-	-	-
Methods assessing workload on upper limbs				
HSE UL	-	-	-	-
Stetson's checklist	-	-	-	Moderate
RULA	Low-Moderate (tech. measures, SI, ACGIH HAL, OCRA)	X	-	Moderate-good
Keyserling's Cumulative trauma checklist	Moderate (video, workplace data)	-	-	Low-Moderate
Strain index (SI)	Moderate (RULA, ACGIH HAL)	L, X	Moderate-good	Moderate-good
OCRA	Moderate (SI, RULA, ACGIH HAL)	X	-	-
ACGIH HAL	Moderate (video, SI)	L, X	Good	Moderate
Washington State ergonomic checklists	-	X	-	Moderate
Ketola's upper limb expert tool	Low-moderate (tech. measures)	-	-	Moderate

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Table 8 continued

Method	Correspondence with 'valid' reference	Association with MSDs*	Intra-observer repeatability	Inter-observer repeatability
Methods assessing workload on upper limbs				
HSE UL	-	-	-	-
Stetson's checklist	-	-	-	Moderate
RULA	Low-Moderate (tech. measures, SI, ACGIH HAL, OCRA)	X	-	Moderate-good
Keyserling's Cumulative trauma checklist	Moderate (video, workplace data)	-	-	Low-Moderate
Strain index (SI)	Moderate (RULA, ACGIH HAL)	L, X	Moderate-good	Moderate-good
OCRA	Moderate (SI, RULA, ACGIH HAL)	X	-	-
ACGIH HAL	Moderate (video, SI)	L, X	Good	Moderate
Washington State ergonomic checklists	-	X	-	Moderate
Ketola's upper limb expert tool	Low-moderate (tech. measures)	-	-	Moderate
Methods assessing mainly MMH				
NIOSH Lifting Equation	-	X	-	-
Arbouw	Moderate (NIOSH lifting equation)	-	-	-
Washington State ergonomic checklists	Moderate (NIOSH lifting equation)	X	-	Moderate
NZ Code for MH	-	-	-	-
MAC	-	-	Moderate-good	Moderate-good
ManTRA	-	-	-	-
ACGIH Lifting TLV	Moderate (NIOSH lifting equation)	-	-	-
BackEST	Low-moderate (tech. measures)	-	-	Moderate

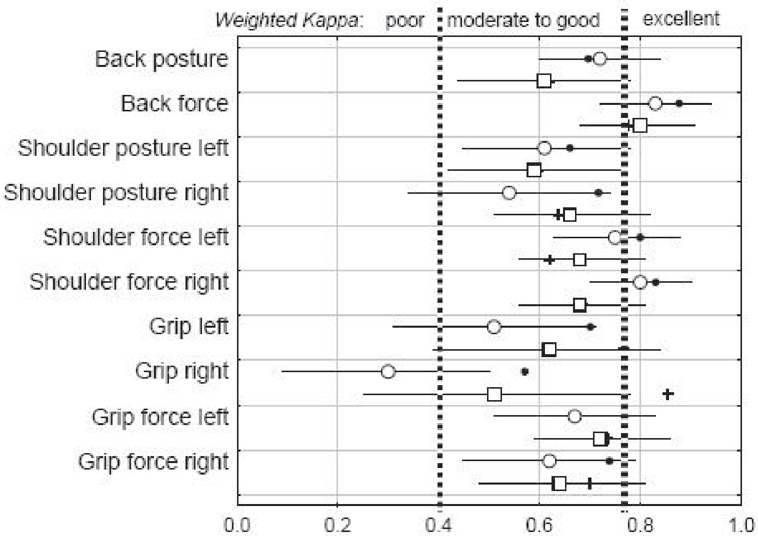
* X=Association in cross-sectional studies, L=Prediction in longitudinal studies

Seven methods included information on intra-observer repeatability and 19 methods on inter-observer repeatability. Intra-observer repeatability was mainly good. Inter-observer repeatability varied from moderate to good, except for REBA for which it varied from low to moderate. Generally the repeatability was better within the subjects than between them.

The practical issues relating to observation methods as judged by the authors are described in the original publication I (Table 3). In particular, check list -type methods were considered easy and quick to use, and therefore they were often viewed as suitable for use by occupational safety practitioners and ergonomists. Computerized registration enables fast recording and analysis of the data, as well as an illustrative output. The most often noted limitations in the use of the methods were that all the relevant factors and/or the interactions of several risk factors were not considered. Moreover, an inadequate definition of observed items, too large number of simultaneously observed items, or the unavailability of software needed to apply the method may cause problems.

6.1.2 Evaluation of the new video-based method (Study II)

Observer pair A&B made a total of 647 observations and observer pair C&D 492 observations. The inter-observer repeatability of observer pair A&B was excellent for back force and for force on the right shoulder, poor for the grip with the right hand, and moderate to good for all other loading factors. For observer pair C&D, it was excellent for back force and moderate to good for the other loading factors (Fig. 3).



□——— Weighted kappa for observer pair A&B with 95% CI

o——— Weighted kappa for observer pair C&D with 95% CI

● Percent agreement for observer pair A&B

+ Percent agreement for observer pair C&D

Figure 3. Inter-observer repeatability between observers A&B, and C&D: agreement (%), weighted kappa values with 95% confidence intervals, and ratings from 'poor' to 'excellent' as proposed by Fleiss (1973.

The proportion of repetitive or continuous awkward postures of the low back and upper extremities as well as the load handled or force needed was lower after the intervention than at baseline. In contrast, the proportion of repetitive or continuous grips increased (Fig. 4). In the expert assessments, loading of the low back was assessed to diminish in 80%, loading of the shoulders in 63%, and loading of the hands and wrists in 49% of the situations. Hence, the direction of these results corresponded to the results obtained by the KILA method, which generally showed a shift to a lower load after the intervention.

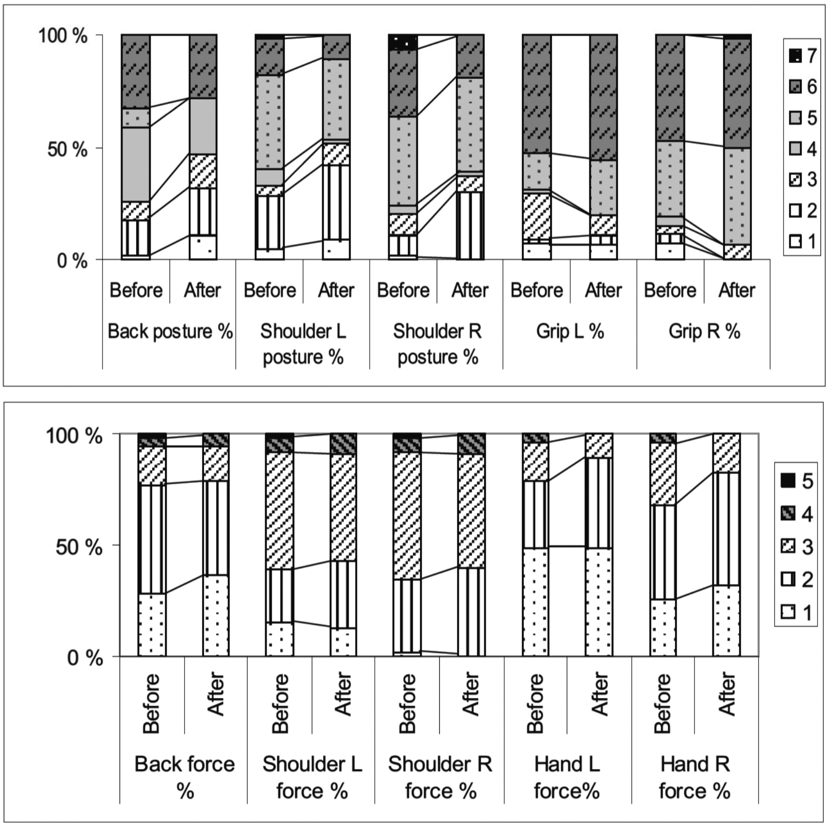


Figure 4. Distribution of ratings (1-7 or 1-5) before and after the interventions. The directions of the lines between bars before and after show the shift of the distribution: Direction upwards means reduction of the loading (back and shoulder postures and forces), and direction downwards means shift to a higher load (grips).

Difficulties were encountered in 21-22% of observation situations by observers. Most often the difficulties were reported when assessing time aspects of postures or grips and force requirements. The observer pair A&B had more often problems in assessing the grips than observer pair C&D (Fig. 5)

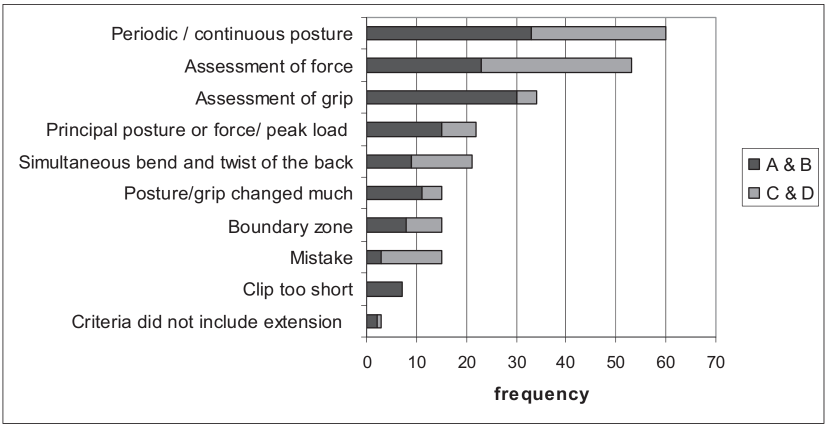


Figure 5. Frequency of problems classified by issue. Observer pair A&B reported 141 difficulties and C&D 104 difficulties.

6.2 EVALUATION OF PARTICIPATORY ERGONOMIC INTERVENTION PROCESS (STUDY III)

6.2.1 Feasibility of the intervention process

Based on the results of the questionnaire, the majority of the workers was satisfied with the intervention process (Fig. 6). The focus group interviews also showed that both the workers and management considered the intervention model as being feasible. On the contrary, based on the questionnaire, the workers were less satisfied with the support from the management and collaboration with the kitchens, and the level of satisfaction varied between the cities (Fig. 7).

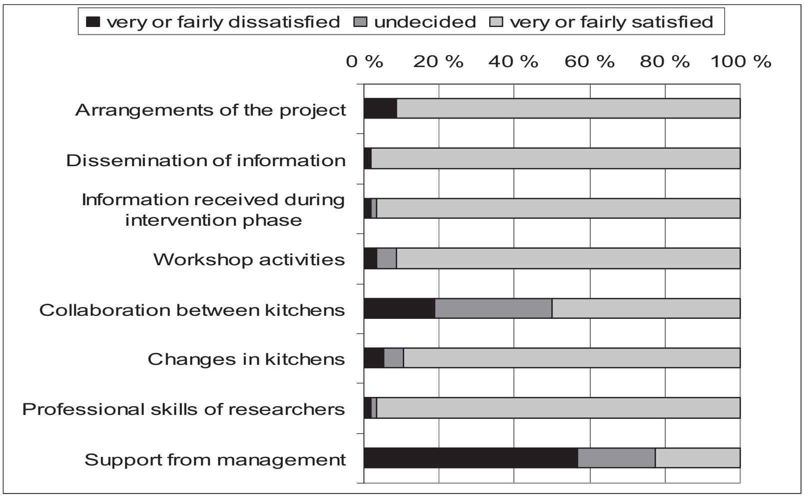


Figure 6. Level of satisfaction with the intervention according to collective responses of kitchens (n=57)

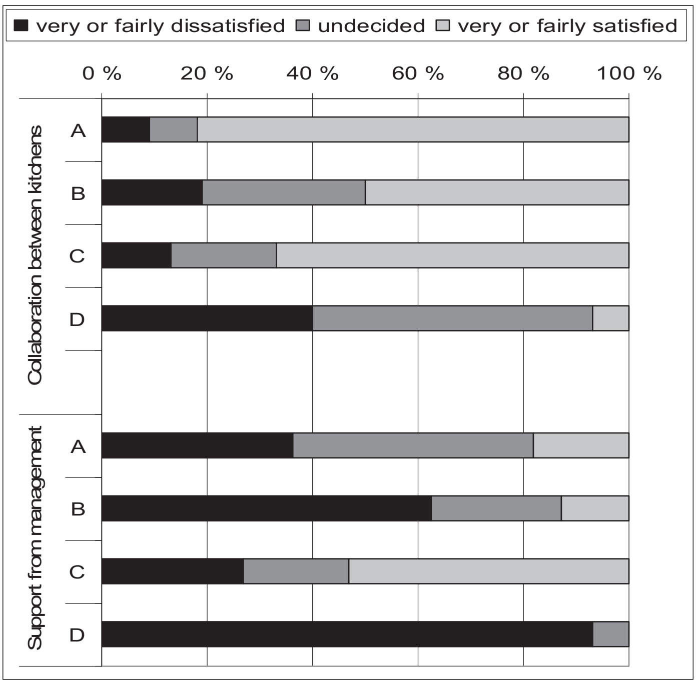


Figure 7. Collaboration between kitchens and support from management by city (A, B, C and D) (n=57 kitchens)

Over 400 changes were implemented during the intervention phase and over 100 changes during the one-year follow-up that were assessed to be beneficial with the regard to the load on the musculoskeletal system or occupational safety. An additional 113 planned changes were interrupted or delayed mainly due to the lack of time or motivation of workers, problems with collaborative partners or technical problems, or lack of financial resources. Sixty to eighty-three procent of the workers participated in the workshops. Management and technical staff participated occasionally with the participation varying between the cities.

6.2.2 Effects of the intervention process

During the intervention phase, 402 changes were implemented. Most commonly the changes were targeted to organization, methods, or practices at work (41%) or to machines, equipment or tools (27%) (Table 9).

Table 9. Targets of implemented changes (n=402) during the intervention phase. 'Layout and furniture' denotes changes in fixed structures (e.g. new shelves or reinstallation of old ones), 'materials' denotes changes for example in package size, and 'work environment or safety' for example removing objects presenting risk of injury.

Target	%
Layout, furniture	13
Machines, equipment, tools	27
Work organization, methods and practices	41
Materials	6
Physical work environment, safety	10
Other	3

Both at baseline and after the intervention phase a total of 70 workers responded to the questionnaires about ergonomic knowledge. Three out of every four of them had participated five to six times in the workshops. Their knowledge in ergonomics increased statistically significantly (mean rating of the ten statements increased from 3.5 to 4.4), whereas the mean rating of workers that participated zero to four times showed a slight but non-significant decline (from 4.6. to 3.8).

In general, the workers' expectations for the effects of the intervention at baseline were more positive than their assessments of effects at the end of the intervention phase. The difference between expectations and perceived effect was greatest in the question related to influence on the health of the musculoskeletal system: before the intervention, three of four workers thought that the intervention would have much or very much influence, but after the intervention that proportion had declined to 40% (Fig. 8).

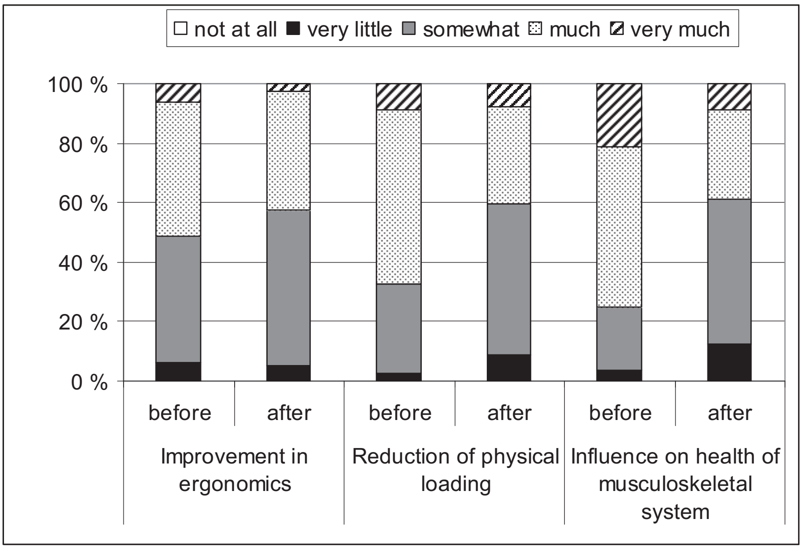


Figure 8. Workers' expectations of the effects of the intervention before the intervention and their similar assessments after the intervention (n=80 kitchens)

6.3 ASSOCIATION BETWEEN CHANGES IN WORK LOAD AND FUTURE SHOULDER SYMPTOMS (STUDY IV)

6.3.1 Shoulder symptoms

Among the 376 female kitchens workers, the three-month prevalence of shoulder pain was 34% at baseline and 41% at one-year follow-up. Three out of every four of the workers who had experienced shoulder pain at baseline had pain also in follow-up. Twenty-three percent of workers with shoulder pain at follow-up reported considerable trouble (rather much, much or very much) due to the pain. Of the workers with no symptoms at baseline, 23% developed shoulder pain during the one-year follow-up.

6.3.2 Reduction in self-perceived work load and shoulder symptoms

At baseline, the workers perceived receiving and storing the incoming raw material, dishwashing, and cleaning and maintenance as the most strenuous work tasks (Fig. 9). The decrease in the strenuousness of receiving and storing, dishwashing and cleaning and maintenance were associated with lower risk of shoulder pain as well as trouble due to the pain at follow-up, when compared to those workers who noted no decrease in the strenuousness of their work tasks (Fig. 12).

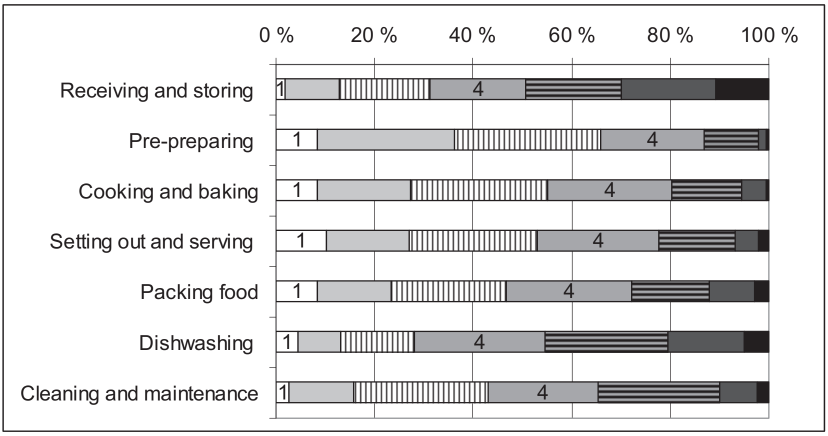


Figure 9. Self-perceived strenuousness by work tasks. 1='not at all strenuous' ... 7='very strenuous'

6.3.3 Reduction in observed exposure and shoulder symptoms

Observation data were available from 69 kitchens with 183 workers. At baseline, high exposure values in lifting were observed most often in receiving and storing raw food, in which the highest exposure value was detected in 75 % of observations (Fig. 10). In addition, dishwashing, setting out and serving food, and packing food included lifting, but the levels of harmful lifting were much lower than in receiving and storing. Working with elevated upper arms was most common in dishwashing and cleaning and maintenance (Fig. 11).

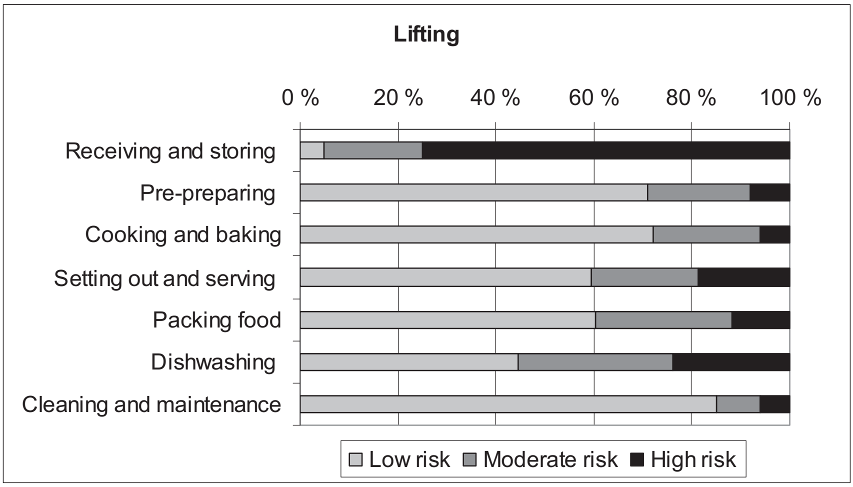


Figure 10. Observed exposure of lifting subdivided according to work tasks at baseline. n=55-427 observations per work task.

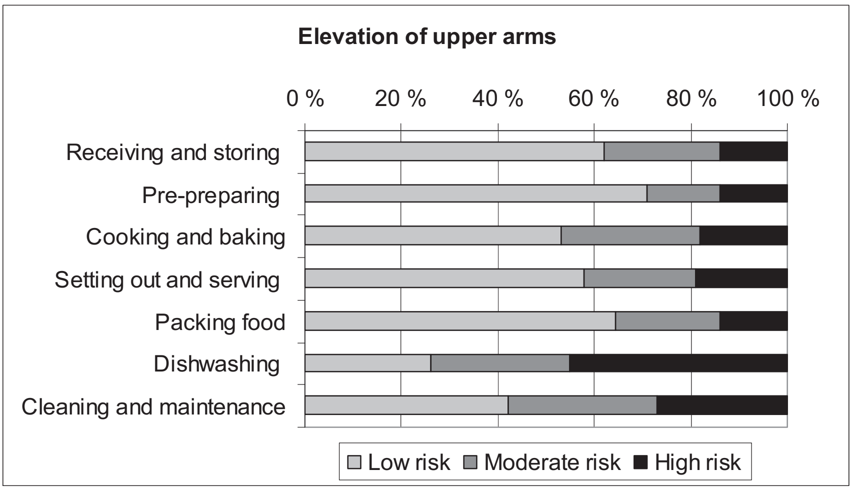
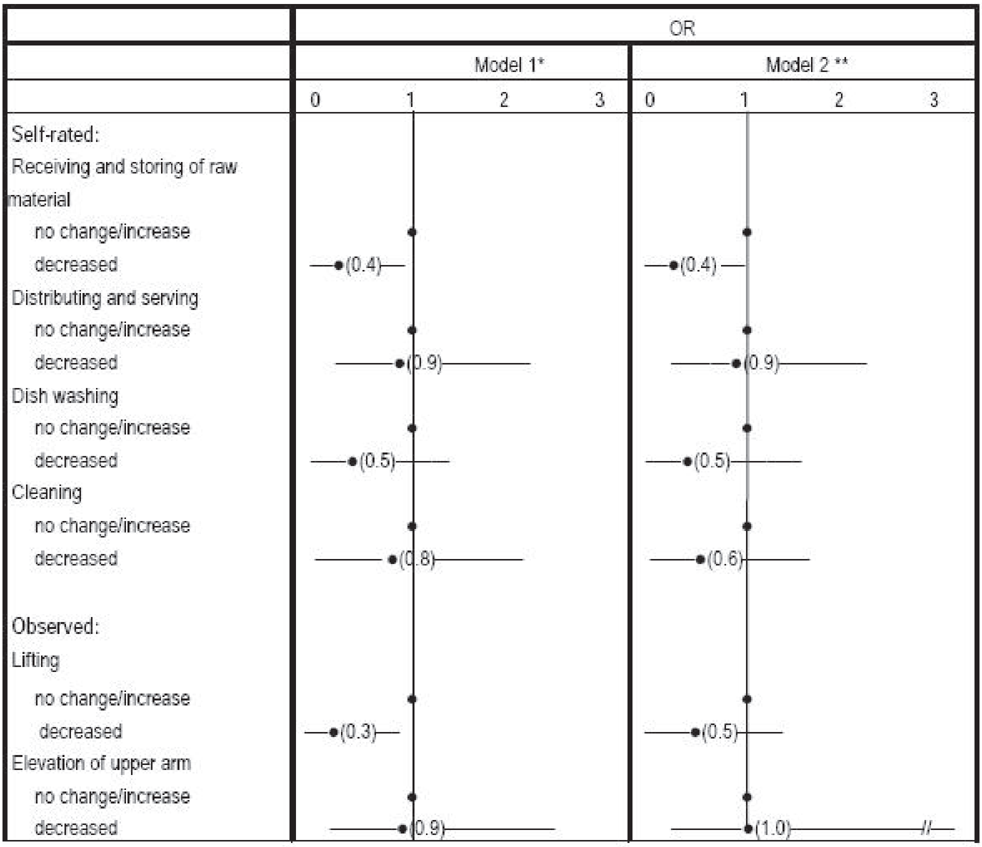


Figure 11. Observed exposure of elevation of upper arms subdivided according to work tasks at baseline. n=55-427 observations per work task.

The reduction in exposure in lifting was associated with a decrease in the risk of future shoulder pain, but this was not the case with an elevated upper arm (Table 11).



* adjusted for shoulder pain at baseline

** adjusted additionally for age, group, and job control

Figure 12. Adjusted odds ratios for self-rated and observed changes in exposures and shoulder pain at follow-up with 95% confidence intervals (—)

7 Discussion

7.1 MAIN FINDINGS

7.1.1 Observational methods to assess physical loads imposed on the musculoskeletal system (Study I and II)

Exposure assessment strategy

The aim of the study was to collect information for users of observational methods to help them choose an appropriate method. The selection of a method is always a trade-off between utility, usability, and costs. Usability and utility are strongly context-dependent, and hence one must clearly define the goals of the investigation and characteristics of the work, as well as the information on available methods when choosing the method. If the target of the exposure assessment is to solve a practical ergonomic problems at the work place, the usability (e.g. how simple is the method to learn and use?) and face validity (e.g. can the output help in decision making?) of the method are more relevant than the method's capacity to provide exact numerical information (Li and Buckle 1999, David 2005, Dempsey et al. 2005). More accurate information on validity and repeatability is needed in research, in which one wishes to undertake exposure assessment data e.g. for studying dose-response-relationships or effects of an intervention. Observational information can be supplemented with other methods (e.g. interviews, questionnaires, or technical measures), as has been done in some large epidemiological studies (Fallentin et al. 2001b, Hoogendoorn et al. 2002, Bao et al. 2006).

Several observational methods were insufficiently described in the literature, and therefore it was difficult to find all of the relevant information in order to assess the utility and usability of the method. To choose the most appropriate method, the user needs access to basic information: e.g. which are the dimensions and exposure measures included in the method, does the method take into account the interaction of the exposures, and does the method help in making decisions. In addition, practical experiences in different contexts and in different user groups would be valuable, but they are seldom reported in scientific reports.

In addition to the selection of the method, the sampling strategy has an important role in determining the credibility and interpretation of the results. Inappropriate sampling may be one reason that even major changes in physical exposures can not be demonstrated in intervention studies (Burdorf 2010). However, information on sampling was only rarely provided in the reports. The group exposure measurement approach is widely used, especially in large studies, due to the lower resource demands. The main concern of this approach is the variability between workers. This variability, as well as variability within and between days, has to be carefully considered when selecting sampling between fixed intervals (e.g. OWAS, PATH), continuous observation (e.g. PEO, TRAC), and even a random sampling.

Observational methods in the kitchen ergonomics study

In the kitchen ergonomics study information was needed on physical exposures in each work task in order to target the interventions. In addition, more detailed information was necessary to detect possible changes in the work load as a result of the intervention. The characteristics of the kitchen work set challenges for exposure assessment methods. Stereotypic jobs, for example, working in on an assembly line, are relatively quick and easy to observe since they are subject to little variation. There are many previously published observation methods which have been developed for such jobs, but they are not suitable for fast-changing and variable kitchen work which puts burden on several body parts. Especially in municipal kitchens, the workers perform many different tasks during the work day. The mornings start by pre-preparation tasks, followed by cooking and baking, setting out and serving food, and in some kitchens by packing food to be delivered to customers. The main tasks in the afternoons are dishwashing as well as cleaning and maintenance of kitchens and equipment. Receiving and storing of incoming material are performed often in parallel with other tasks, generally in the morning. Hence, in order to attain a general view of the physical work load, it was necessary to observe work tasks during the entire working day in each kitchen.

In the kitchen ergonomics study, two observation methods were developed — an expert observation method and the KILA method. The expert observation method was developed mainly for targeting interventions. In this method, a relatively coarse, three point scale was chosen for the evaluation of risk factors, due to the large number of simultaneously observed variables and the fact that the ergonomists had to observe work tasks for the entire working day. A large category size and a low number of the categories have been found to decrease both decision time of the observers and misclassification error. However, the disadvantage has been that with larger category size misclassification may be associated with a higher magnitude of error (van Wyk et al. 2009). In the present study, the method included all of the relevant risk factors for musculoskeletal disorders and the scale was found to be accurate enough to identify the most important risks in each work task. Most of the observation criteria were logical and similar to previous observation methods. The method was not too demanding for the observers in assessing work tasks for the entire working day. However, it might not to be sensitive enough to reveal the changes in exposures, if the ergonomic changes are minor. The evaluation of the use of hand force was considered difficult (Stenholm 2003).

The KILA method was developed to provide more accurate information on changes in musculoskeletal load. Therefore a seven point scale was used in assessing postures, and four to five point scales in assessing force requirements. The KILA method emphasizes the importance of both duration and repetitiveness of a loading factor. Observation in real time enabled linking of the time aspects with the assessment of posture and hand grip. The method is based on the assumption that a less awkward posture with long duration or a high repetitiveness may be more loading than a more awkward posture which lasts for a short time or is not repeated often (Winkel and Mathiassen 1994, Mathiassen 2006).

As in previous studies, the assessment of force requirements was reported to be problematic by observers (van der Beek and Frings-Dresen 1998, Marshall and Armstrong 2004). The observation was challenging especially in the kinds of tasks in which the force requirements were affected by factors other than the weight of the object (e.g. in wiping tables), as well as in pushing, pulling, and gripping. In the KILA method, the assessment of hand load was supported by giving examples of kitchen work. However, even then the assessment was difficult, especially if the observer was not truly familiar with the observed task. Marshall and Armstrong (2004) studied the subjects' ability to identify force levels of daily activities (e.g. eating with fork/spoon, dish washing, shovelling snow) and they noted that considerable variability existed in the perception of the force requirements. Nonetheless, they concluded that these kinds of lists might be a useful tool when assessing force requirements e.g. in rehabilitation and clinical settings. In general, if one wishes to obtain more accurate results, feedback of the workers performing the tasks could be utilized and direct measurements should be used to supplement the observations of force requirements (Juul-Kristensen et al. 1997, van der Beek and Frings-Dresen 1998).

Another commonly reported difficulty with the KILA method was the assessment of time aspects: combining the assessment of repetition and duration with the posture or force requirements proved to be challenging for the observers. Difficulties in distinguishing between occasional and continuous postures were encountered, especially when the duration was close to the cut-off point between two categories. This finding is in line with earlier studies that have identified and discussed these kinds of boundary zone problems as well as difficulties in assessing duration (Keyserling 1986, Stetson et al. 1991, Denis et al. 2002, Lowe 2004, Lowe and Krieg 2009).

In earlier studies, micropostures, such as the postures of hands and wrists have been found to be difficult to observe with adequate accuracy (Stetson et al. 1991, Ketola et al. 2001, Lowe 2004). Therefore in the KILA method, hand load was assessed according to the type of grip. However, also this method proved to be demanding in studying the fast-changing kitchen work.

Validity

The concept of validity includes several aspects (Last et al. 1995, Streiner and Norman 1995). In our review, criterion validity was assessed in terms of concurrent validity by comparing the method with another measurement method considered to be more valid. Of the 30 methods, about two thirds were compared with some other method(s).

Only eight observation methods were validated using technical measurements. The correspondence of observations and technical measures has mainly been moderate or low (Burdorf et al. 1992, DeLooze et al. 1994, Leskinen et al. 1997, Ketola et al. 2001, Village et al. 2009). One possible explanation for the different results may be a misclassification error, which is obvious especially when a large amount of events occur near the boundary zone of two categories (Keyserling 1986, Fransson-Hall et al. 1995, Stetson et al. 1991, Denis et al. 2002, Lowe 2004, Andrews et al. 2008). Another reason may be that technical measurements are usually continuous, whereas observations have often been conducted with sampling of fixed time intervals (Burdorf et al. 1992, DeLooze et al. 1994, Buchholz et al. 1996, Village et al. 2009).

Some methods have been validated by comparing work-site observations with film-recordings. The agreement has mainly been moderate to good, and it has been better when assessing macropostures and work actions than can be obtained with micropostures, such as postures of wrists and hands or neck (Leskinen et al. 1997, Stetson et al. 1991, Ketola et al. 2001, Lowe 2004).

Some observation methods have been compared with other observation methods. One method can be regarded as a validation reference, if it is able to provide more accurate information and the methods are measuring the same phenomenon. However, often the reference method has not proved to be more valid, the methods that have been compared have included different categories (Juul-Kristensen et al. 1997), or they have been measuring different risks (e.g. RULA vs. Strain index (Drinkaus et al. 2003)). Therefore many of these studies can actually be considered as a comparison of methods rather than validation.

The validity of the KILA method was evaluated by comparing the direction of the changes with those identified by the experts (Expert assessment of implemented changes is described in chapter 5.3. The results given by two methods were mainly in accordance, except for those relating to the load of the hands: the KILA method identified an increase in load, whereas the experts did not report similar effects. Nonetheless the results are not directly comparable — the experts assessed the changes in a more general manner, whereas with the KILA method, one particular worker performing one specific work task was observed — however, it can be stated that the criteria for assessing wrist and hand loading need to be further elaborated and clarified. Subsequently, the method should be validated more accurately e.g. against measurements of the angles of the postures, force requirements, and duration of the exposures.

In this thesis also another aspect of concurrent validity, predictive validity, was addressed, i.e. whether the findings of an observation method were associated with musculoskeletal disorders. One-third of the analyzed observational methods were found to be associated with MSDs, but the majority of them have been tested in cross-sectional settings only. Moreover, only a few cohort studies have analyzed the correlations using terms such as sensitivity and specificity that can support the conclusions on predictive validity (Moore et al. 2001, Gell et al. 2005, Werner et al. 2005a, Werner et al. 2005b, Werner et al. 2005c, Werner et al. 2005d, Werner et al. 2005e, Violante et al. 2007, Spielholz et al. 2008).

The predictive validity of the KILA method was not studied. In Study IV it was found that another method developed in this study, the expert observation method, was associated with shoulder pain: the reduction in observed physical work load predicted future shoulder symptoms. Even though the method was developed mainly for targeting interventions with a relatively coarse scale, it did detect changes in work load and showed the risk factors to be associated with musculoskeletal pain.

Repeatability of the methods

Among the 30 methods examined in our review, intra-observer repeatability was reported for seven methods and inter-observer repeatability for 17 methods with both being mostly reported to be moderate or good. In general, when both within- and between-observer repeatability were studied, intra-observer repeatability was better than inter-observer repeatability.

In addition to features of the method several other aspects, e.g. the experience and training of the users, study design and setting, observed material, sample size, and statistical methods used may have an effect on repeatability of the method (Kilbom 1994, Denis et al. 2000, Bao et al. 2009). The methods in which the observers had trained their skills until a sufficient agreement was reached (TRAC (van der Beek et al. 1995), PATH (Buchholz et al. 1996)) showed a good rating of repeatability in our evaluation. For most methods, the duration of training needed for the users to be able to use the method properly has not been documented. Trials with observations based on video or photographs have provided a better agreement than those conducted at the workplace. In addition, the number of events occurring on the boundary zone between two categories may have an effect on repeatability. Therefore numerical statistics related to repeatability between the trials and methods have to be interpreted cautiously.

Agreement between the observers would be expected to be lower when there are a high number of exposure categories. Nonetheless, even though the number of exposure categories in the KILA method was as many as seven, the inter-observer repeatability was mainly moderate or good. It was noted that the observer pair with less experience (A&B) had a higher proportion of agreement than the more experienced observer pair. One reason could be that A&B had recently observed kitchen work as a pair and thus had shared a common experience.

7.1.2 Evaluation of a participatory ergonomic intervention in kitchen work (Study III)

One aim of the participatory ergonomic intervention in kitchen work was to increase the ergonomic literacy of the workers. The learning of the workers was emcouraged by several ways. First, the ergonomists taught the basics of ergonomics to the workers in workshops, which also included practical learning. Second, the workshops were held alternately in each kitchen of a series. Hence, the workers were given the opportunity to become acquainted with other kitchens and share ideas and experiences with the other participants, and to learn from each other. The workers considered this to be very useful and in fact they wished that there had been more time for this aspect of the work. Visiting other workplaces in the same type of workplace was also applied in a previous study, but only small representative groups of workers took part in these visits (Wilson 1995). In our study, all of the workers had the possibility to see other work environments. Third, learning was additionally supported with an idea folder, in which all good practices of all kitchens were gathered. The idea folder could be accessed by all workers at workshops and this improved the dissemination of good ideas from one intervention kitchen to next.

Learning to develop work in teams was also important. Although kitchen workers work as a team in kitchens, the participatory approach and development as a team was new a concept for them and it was considered difficult in some kitchens by the workers at the beginning of the project. Therefore training and more extensive support at the beginning of the project could have helped them to initiate the development process in a more dynamic manner (Gjessing et al. 1994).

In the review on participatory ergonomic intervention, 11 of the 23 studies provided ergonomic training as a part of the intervention. In all those studies, the workers were trained and in the half of them also the representatives of the management participated in the training (Rivilis et al. 2008). In our study, it was mainly the workers who participated in the training. However, the management is usually responsible for financial matters as well as purchasing equipment and material. Hence, it is crucial that they have a good literacy in ergonomics.

According to the questionnaire and focus group interviews, the workers' level of ergonomic knowledge and awareness of ergonomic aspects increased, which obviously improved their confidence and ability to tackle ergonomic problems in their workplace. The general knowledge in ergonomics was associated with the participation activity in the workshops, suggesting that the workshops had achivied their goal in disseminating information.

Participatory ergonomic intervention processes can be conducted in numerous ways. Often the educational background of the participants may be heterogeneous, and therefore tools have to be practical and concrete (Kuorinka 1997). In the kitchen ergonomics study several types of data on needs for the intervention (i.e. what would be the targets of the intervention and how these targets could be reached) were gathered before the intervention. Data on strenuousness of the work tasks, as well as the workers' level of ergonomic knowledge and expectations were collected with questionnaires, risk factors were observed by researchers, work tasks were recorded on video, and workers were interviewed. However, it was not possible to utilise all these data when planning the intervention process. One reason was that widely tailored interventions were not possible to conduct in a strictly controlled study design with a large number of intervention kitchens. In addition, due to tight schedules, some questionnaires (e.g. knowledge in ergonomics and expectations of the workers on intervention) were developed after the onset of the study and therefore they could not be carried out at the baseline in all kitchens. In the first workshop, data about the strenuousness of the work tasks in each kitchen and general information on risk factors was presented to the workers. Photographs of workers performing loading tasks and different kinds of questionnaires were used when identifying and analysing work situations with ergonomic risks. However, it has to be conceded that video material might have been more illustrative.

The workers analyzed their work tasks by using the problem identification grids developed for this study, but they considered this kind of paperwork tedious. Thus, a more practical method might have been more useful. Nonetheless, there are very few methods that can be used in participatory ergonomic intervention trials to determine the risk factors by the workers in groups. One promising method is VIDAR, in which the worker or group of workers assess physically or psychosocially demanding situations by watching a video recording. The method has been used for assessing exposures in tasks loading the entire body, such as those performed by nurses and physiotherapists, and it might be a potential method also for kitchen workers (Kadefors and Forsman 2000, Forsman et al. 2003, Forsman et al. 2006, Väyrynen and Saaranen 2006).

Based on focus group interviews, the kitchen workers appreciated that their work had been chosen as the target of the study. The workers thought that they would have a good possibility to affect their own work and working conditions, and they had high expectations of the effects on the ergonomics, musculoskeletal load, and MSDs before the intervention phase. However, their assessments after the intervention concerning the same aspects were lower. One explanation may be that they were disappointed, because a large number of planned measures — over 100 — were never implemented or their implementation had been delayed. Often the workers reported that their wishes had not been taken seriously. Thus, one disadvantage of PE might be that it can raise hopes which cannot always be fulfilled.

As in previous studies, the main hindering factors for implementation of changes were lack of time and poor motivation of the workers (Rosecrance and Cook 2000, Whysall et al. 2006). Our participatory model was intensive and time-consuming (total 28 hours / worker) compared with several previously conducted studies (Rivilis et al. 2008). In addition, the workers developed their work themselves in their own kitchens between the workshops and this was sometimes challenging, especially on busy working days. Limited financial resources might have been one reason for the low motivation. The kitchens did not receive any extra funding to accomplish the changes and therefore the majority of the changes in kitchens were minor, targeted at low-cost solutions, as well as changes in working methods and practices. Other reasons for low motivation may be a lack of support from food service management and technical staff and poor communication between them and the workers. The importance of an enthusiastic and supportive management in the implementation of interventions has been emphasized in previous participatory studies (Vink et al. 2006, Whysall et al. 2006). The participation of different stakeholders may have a positive effect on communication between different groups, and the workers may find it easier to sell their ideas to the other groups. Without proper support and active communication, the intervention may end up focusing on minor and micro-level changes rather than on more extensive ones at the macro level. However, one disadvantage of the participation of stakeholders may be that it may limit discussions between workers (Gjessing et al. 1994).

In this study, the participation of the management and technical staff varied in the workshops between the series and between cities. Low participation may be partly related to the fact that the role of the food service management was not made clear enough at the beginning of the project. Later during the study, the ergonomists encouraged the food service management and technical personnel to participate more actively and this seemed to have a positive effect on participation. In particular in two cities, the majority of the workers were not satisfied with the support from the management and this was found to be associated with the effects of the intervention: the more satisfied the workers were with the support, the more positively they evaluated its effect.

In general, the participatory approach proved to be feasible and motivating, the workers' knowledge and awareness in ergonomics increased, a remarkable number of changes were implemented, and the workers reported positive effects on physical load and musculoskeletal health. Nevertheless, no systematic changes were detected in the main outcome of the core study, i.e. musculoskeletal disorders, and even deterioration was seen in psychosocial factors at work. The unfavourable effects were mainly found to be due to a joint effect of the intervention and unexpected organizational reforms of foodservices in two of the participating cities. In addition to feelings of uncertainty, the combination of the intervention study simultaneously with the implementation of the reform may have been too stressful to the workers (Haukka et al. 2008, Haukka et al. 2010). Organizational reforms may change the needs of the workers and affect the facilitators and barriers of the process. Therefore when unexpected organizational changes occur simultaneously with a planned intervention, it might be beneficial to return to the need assessment, to reconsider the timing and needs, and adjust the process, if necessary.

7.1.3 Association between reduction in work load and future shoulder symptoms (Study IV)

Shoulder pain proved to be common among kitchen workers. At the one-year follow-up the prevalence of shoulder pain was 41% and every fourth worker had developed a new episode of shoulder pain during this one-year time period. As in earlier studies (van der Windt et al. 1996, Luime et al. 2005,), the shoulder pain was very persistent (or recurrent): 75% of those with pain at baseline still had pain one year later. This stresses the importance of early prevention of the shoulder problems.

According to the workers' perception, the most physically strenuous tasks were receiving and storing of incoming raw food material, dishwashing, and cleaning and maintenance. A reduction in the self-perceived and observed physical work load decreased the risk of future shoulder symptoms, especially in the receiving and storing of incoming food material, which was perceived as the most loading task. Our result is in line with Westgaard and Winkel (1997), who proposed that a reduction in mechanical exposure might be beneficial for musculoskeletal health in work situations where mechanical exposure is initially high.

This study revealed that kitchen workers are exposed to a high level of lifting. Especially receiving and storing, and dishwashing include frequent lifting of heavy loads, which in earlier studies have increased the risk of shoulder disorders (Hoozemans et al. 2002b, Harkness et al. 2003, Smedley et al. 2003). In a Finnish prospective population-based study, lifting heavy loads increased the risk of developing a clinically diagnosed chronic shoulder disorder twenty years later, particularly in older workers and women (Miranda et al. 2008).

In our study, the observed reduction in working with elevated upper arms was not associated with future shoulder pain, even though in previous studies it has been considered as a risk factor for shoulder complaints (Harkness et al. 2003, Miranda et al. 2005, Sim et al. 2006, Larsson et al. 2007). One explanation for our results may be the long latency period: the exposure levels for elevated upper arm postures were relatively low and sometimes a reduction in low-level exposure will not immediately result in any improvement in musculoskeletal health (Westgaard and Winkel 1997, Burdorf and van der Beek 1999). Another explanation may be that the repeatability of the observations for upper arm elevation was only moderate. Other studies have also shown that it is challenging to undertake an objective assessment of upper arm posture (Burt and Punnett 1999, Ketola et al. 2001).

7.2 METHODOLOGICAL ASPECTS

7.2.1 Review of observation methods (Study I)

The guidelines of systematic reviews (Moher et al. 1999, Stroup et al. 2000, Higgins and Green (updated September 2009)) stress the importance of systematic search strategies in electronic databases. One strategy is to use pre-defined search terms and their combinations. However, in this study, it was noted that all relevant publications could not be identified with this system. Therefore the search was continued in further ways, e.g. with the names of the methods as well as using the option of 'related articles' and reference lists of publications. Mainly scientific articles and text-books published in English were identified. In addition, some reports in German, French, Italian, and Scandinavian languages were accepted. Those references were excluded that could not be accessed via public deliverance (e.g. commercial methods, academic studies, and conference books not available over the internet). Furthermore only those methods were included in which observations were a principal component. However, since the extensive searches and the fact that the members of the working group were active researchers in this field it can be postulated that most of the observational methods used for the assessment of physical workload were probably identified.

There are no standard procedures available with which to evaluate observation methods. Therefore a framework was developed for evaluation by utilizing an international group of experienced researchers. The selection of items to be evaluated was based on general knowledge on the needs of assessment of physical workload in the practice, as well as on the research on occupational health and safety (Kilbom 1994, Winkel and Mathiassen 1994, Westgaard and Winkel 1996, Wells et al. 1997, Li and Buckle 1999, David 2005). All evaluators also participated in the development of the evaluation process, in which a similar concept was achieved. Each method was assessed independently and blinded by at least two evaluators.

7.2.2 Video-based observation method (Study II)

The repeatability of the KILA method was studied by observing the work tasks independently from video recordings by two observers. The systematic observation bias was minimized by showing the video clips in a random order and ensuring that the observers were unaware of interventions. Since several factors had to be observed from one video clip, the observers had the opportunity to view the video clips three times and concentrate on one body part at a time in order to improve the repeatability and validity of the assessments.

The usability of the observational method and the problems encountered by the observers have been seldom studied (Denis et al. 2000, David et al. 2005). Information was collected on problems in observation by recording the discussions of the observers as they came to their consensus assessments, and subsequently classified problem situations. The limitation of this method was that even though the observers were requested to discuss all the problems they had encountered during the observations, they most likely did not report all the problems systematically.

The observation material might also be a reason for the inaccuracy in the exposure assessment (Spielholz et al. 2001, Bao et al. 2009). Our material was recorded in actual work situations, and sometimes the same worker was not videotaped on both occasions, i.e. before and after the intervention. Hence, the anthropometric dimensions and personal work habits might have affected the results. In addition, the quality of the video recordings might have had an influence on the accuracy of the assessments. Our video material was recorded using one camera mainly from the sagittal view. In this view, it is easy to observe trunk and shoulder flexion, whereas the observation of the trunk bent laterally and shoulder abduction is more difficult. In addition, it may sometimes be impossible to see all body parts, e.g. when an extremity is behind the body or some other factor, such as working object is blocking the view (Lowe 2004, Sutherland et al. 2007, Bao et al. 2009). In order to improve the quality of the observed material, guidelines on how to conduct the video recording should be included in the manuals of the methods in which observations are performed from videotape. When several body parts are being assessed at the same time, the use of at least two cameras is recommended.

7.2.3 Evaluation of intervention (Study III)

Ergonomic intervention studies have rarely been evaluated in a structured way, possibly partly because no general framework exists on how to carry out an evaluation. In previous studies, the level of workers' knowledge and awareness in ergonomics has been studied with questionnaires (King et al. 1997, Harrington and Walker 2004, Shah and Silverstein 2004). In the present study, the information about the level of knowledge in ergonomics was collected with questionnaires and information on awareness in ergonomics via focus group interviews. The results of different studies are not comparable, because the questionnaires have been different and the questions have been developed mainly for the individual studies. Another limitation is that the questionnaires have not been validated. In our focus group interviews, only representatives of the workers (n=3) were interviewed, which limits the generalization of the results to all workers.

The intervention process was evaluated primarily from the workers' point of view, even though also the representatives of the management were present in the focus group interviews. However, stakeholders (i.e. workers, management, and designers) have often different needs, aims, and priorities in intervention studies and therefore these processes should be evaluated by taking into account also other groups in addition to workers.

One weakness in the documentation of PE processes has been the lack of participation rates in the processes: in the review of 23 PE studies, information on participation rate was included in a fourth of the studies only (Rivilis et al. 2008). In our intervention both the response rates to the questionnaires and the participation rates of the workers in the workshops were high. However, the participation rates of the management and technical personnel were low in general and this varied between the cities.

A limitation of this study was that the control group was not asked about their knowledge in ergonomics. Contamination was probably minor: during the intervention phase only two workers were transferred from an intervention kitchen to a control kitchen and the workers in the intervention kitchens were asked not to talk about the study process with the workers in the control kitchens.

7.2.4 Association between reduction in work load and shoulder symptoms (Study IV)

In intervention studies, it is important to determine not only whether the presence of a certain exposure increases the risk of musculoskeletal disorder, but also whether a reduction in the risk factor reduces pain. In the kitchen ergonomics study, no systematic differences in the prevalence of musculoskeletal pain were found between the intervention and control group (Haukka et al. 2008). No observational exposure analysis was available for all kitchens in control group and therefore subjective assessments were used. In this study on shoulder disorders, the intervention and those control kitchens that had observational exposure data were pooled and the data were analyzed as a prospective cohort. Our study sample consisted only of female kitchen workers; men were excluded due to their low number. The men did not significantly differ from the women with respect to the self-perceived physical strenuousness of work tasks or shoulder pain.

The strength of this study is that the exposure data were collected using two methods: the workers were asked to assess the strenuousness of the work tasks, and the physical exposures were observed by researchers in kitchens. The results given by two methods matched well: work tasks perceived as most strenuous (i.e. receiving and storing raw material, dishwashing and cleaning) included the highest levels of observed shoulder-loading exposures (i.e. lifting and working with elevated upper arms).

In many previous studies, the assessment of the exposures has been based on self-reports of the workers. However, the validity and reliability of self-reporting have been criticized (Stock et al. 2005). In particular, in jobs where the physical exposures co-occur and vary considerably, it may be difficult for a worker to accurately estimate the amount of exposure to e.g., awkward postures or lifting. Hence, it was decided to assess the self-perceived physical strenuousness of the work tasks, which has been earlier used in studying highly variable tasks, such as work tasks of fire fighters, paramedics, and flight attendants (Conrad et al. 2000, Lee et al. 2008). Nonetheless, self-perceived physical strenuousness of the work has also been shown to predict musculoskeletal symptoms and functioning (Miranda et al. 2001, Leino-Arjas et al. 2004). Since self-perception of health or work ability are known to be strong predictors of future morbidity, disability and mortality (Liira et al. 2000, Jylhä 2009), self-perceived strain in individual work tasks could be a useful tool for assessing the physical work load in jobs with wide variation of exposures. This kind of method seemed to suit well for kitchen work, because the work includes several relatively easily separable work tasks with different degrees of strenuousness. Before one can conduct a questionnaire survey on the strenuousness of tasks, the work has to be divided into work tasks, which requires a basic knowledge of the content of the work to be evaluated.

Since both the strenuousness of the work tasks and pain or trouble due to the pain were reported at the same time by the workers, one cannot be sure about the temporal order of the changes. In an attempt to clarify the matter, data using expert observations were collected and analyzed. The experts observed the workers during one full work day in each kitchen at baseline and at follow-up. Since the menu of the day may cause variation in the exposures, the observation days were chosen so that the menus at baseline and follow-up were as similar as possible. The researchers were asked to choose the observed work tasks randomly, but they might have chosen more often physically loading tasks rather than the lighter tasks. Hence, the observed exposure level may therefore be somewhat overestimated. The measurement error probably affected both baseline and follow-up measurements evenly, so this did not affect our results based on the change in exposure. The limitation of the method was that the assessment of lifting was performed only based on the weight of the object, and other factors, e.g. vertical and horizontal distance of weight lifted, were not considered.

Observational data were analyzed using a group approach, i.e. the same exposure level was given to each worker in the same work unit, even though it is known that the exposure levels vary between and within workers. However, if one uses the group-level approach then this will reduce the amount of data that needs to be collected as well as the minimizing random error in the measurements (Jansen and Burdorf 2003).

8 Conclusions

The systematic review showed that the methods to assess physical exposures imposed on the musculoskeletal system have been tested incompletely for repeatability, validity, and usability. The selection of the most appropriate observation method in a certain setting is always a trade-off involving several competing aspects. Therefore the users should thoroughly identify their needs and resources, and focus on the most important aspects (e.g. accuracy of the results or simplicity in use) when choosing the method. Another essential factor is the selection of the sampling strategy, which may have a crucial effect on the results due to the large seasonal and day-to-day, as well as intra- and inter-worker variation in physical exposures.

The kitchen work poses a challenge for exposure assessment due to the highly variable nature of the work tasks. The new video-based observation method (KILA) combined the assessment of the posture or force requirements with the time aspects (frequency and duration). The method showed satisfactory repeatability after a 7-hour training period. It also demonstrated the capability to identify changes in the levels of the exposures before and after the intervention. Based on both the systematic review and the experiences from the KILA method, the assessment of distal and small body parts and fast-changing movements seems to be more difficult than assessment of larger body parts. In addition, the evaluation of actual forces is challenging.

Improving the workers' knowledge and awareness in ergonomics was an essential aim of the participatory intervention and this was achieved in this study. However, one could speculate that more active participation of management and technical personnel as well as better collaboration and communication between workers, management, and technical personnel could have resulted in even better results.

Shoulder disorders are prevalent and persistent among professional kitchens workers. By reducing biomechanical workload, especially lifting, the risk for future shoulder symptoms may be diminished.

9 Recommendations and needs for further research

Validity, repeatability, utility, and usability of existing observation methods should be further investigated. In addition, guidelines about minimal requirements for reporting should be set to facilitate the choice of the most appropriate method. Such guidelines would also assist researchers while evaluating and further developing the methods. A framework for a systematic evaluation of the methods should be developed further.

In addition to the primary outcomes, the evaluation of ergonomic interventions should be expanded to cover the evaluation of the intermediate outcomes and processes. In order to conduct a systematic evaluation, one needs a framework for evaluation. More attention should also be paid on collecting appropriate data on knowledge, attitudes, and behaviours of the target population as well as the context in which the intervention will be carried out (need assessment), and these data should be utilised in the development of the process and tools for implementation.

In participatory ergonomic studies, there is a need for exposure assessment methods suitable to be used by participants in assessing targets for the intervention. Furthermore, in all ergonomic intervention studies, new methods are needed to better capture changes in different dimensions (amplitude, frequency, and duration) of exposure after an intervention. Work tasks requiring high levels of lifting should be the subject of special attention in risk assessment and planning preventive measures.

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APPENDIX

Table 1. Summary of selected reviews on risk factors of MSDs.

Outcome / Reference	Detected risk factors
Neck or neck/shoulder pain or disorder	
Neck pain or disorder (Ariëns et al. 2000)	Neck flexion, high arm force, elevated arm posture, long duration of sitting, twisting or bending of the trunk, hand-arm vibration
Pain in neck-shoulder area (Côté et al. 2008)	High quantitative job demands, sedentary work position, repetitive work, precision work and awkward neck work postures, working with hands above the shoulder
Neck pain (Hansson 2001a)	Work with bent or twisted trunk
Chronic neck pain or neck-shoulder girdle pain with physical finding(s) (Palmer and Smedley 2007)	Repetition at the shoulder or at the wrist-hand, neck flexion allied with repetition, neck flexion with respect to static loading, force in the absence of repetition
Shoulder pain or disorder	
Shoulder pain or disorder (Styf 2001	Highly repetitive, static work with the arms abducted or elevated
Shoulder pain (van der Windt et al. 2000)	Heavy physical work load, awkward postures, repetitive movements, vibration
Elbow, hand and wrist pain or disorder	
Epicondylitis or nerve entrapment at the elbow (van Rijn et al. 2009a)	Lateral epicondylitis: handling tools > 1kg, handling loads > 20 kg at least 10 times/day, repetitive movements > 2h/day Medial epicondylitis: handling loads > 5kg, handling loads > 20 kg at least 10 times/day, repetitive movements > 2h/day, high hand grip forces for >1h/day, working with vibrating tools >2h/day Cubital tunnel syndrome: holding a tool in position Radial tunnel syndrome: handling loads > 1kg, static work of the hand during the majority of the cycle time, full extension of the elbow
Epicondylitis (Vingård 2001a)	Combined exposure of repetitive and heavy work
Carpal tunnel syndrome (van Rijn et al. 2009b)	High levels of hand-arm vibration, prolonged work with a flexed and extended wrist, high hand force, high repetitiveness, combination of risk factors
Carpal tunnel syndrome (Palmer et al. 2007)	Regular and prolonged use of hand-held vibratory tools, prolonged and highly repetitious flexion and extension of the wrists especially with a forceful grip
Carpal tunnel syndrome (Vingård 2001b)	Working with hand-held vibrating tools, highly repetitive work with the hands, power grip, combined exposure
Low back pain (LBP) or disorders	
Low back pain or disorder (Hansson 2001b)	Frequent heavy lifts, awkward postures, physically heavy work
Low back pain (Hoogendoorn et al. 1999)	Manual materials handling, bending and twisting, whole-body vibration, patient handling, heavy physical load
Low back disorder (Kuiper et al. 1999)	Manual materials handling
Low back pain (Lötters et al. 2003)	High exposure to manual handling, frequent bending and twisting , and whole-body vibration

Table 2. Original studies on shoulder pain and disorders published after year 1998 (after the review of van der Windt).

Field/reference	Design/ population	Outcome	Results
Work in a slaughterhouse or a chemical factory (Frost and Andersen 1999)	Cross-sectional / 743 workers, 398 referents	Impingement syndrome (shoulder symptoms $\geq$ 3 months during the past year)	Shoulder intensive work is a risk factor for impingement syndrome of the shoulder.
Automobile assembly work (Punnett et al. 2000)	Case-control / 79 workers, 124 referents	Self-reported shoulder pain and clinically defined shoulder disorder	Severe flexion or abduction of the shoulders associated with shoulder disorders. Duration of the work cycle and use of hand-held tools increased risk.
Repetitive work (Frost et al. 2002)	Cross-sectional / 1961 workers, 782 referents	Self-reported shoulder pain and clinical finding on shoulder tendinitis	Repetitive work, high frequency of shoulder movements, high force requirements, and lack of micropauses, and especially combination of risk factors were associated with shoulder complaints
Pushing and pulling tasks (Hoozemans et al. 2002a)	Prospective / 459 workers	Self-reported trouble	Pushing and pulling were rather strongly associated with shoulder complaints.
(Harkness et al. 2003)	Prospective / 803 workers	Self-reported shoulder pain	Lifting heavy weights, carrying on one shoulder, lifting at or above shoulder level, pushing and pulling, and working with hands above shoulder level were predictive of new onset of shoulder pain
Repetitive work (Leclerc et al. 2004)	Prospective / 589 workers	Self-reported shoulder pain	For men, repetitive use of a tool and for women, use of vibrating tools and working with arms above shoulder level were associated with incidence of shoulder pain.
Representative population sample of persons aged $\geq$30 years (Miranda et al. 2005)	Cross-sectional / 3831 persons	Clinically diagnosed chronic rotator cuff tendinitis and self-reported nonspecific shoulder pain	Cumulative exposure of working with hand above shoulder level had strong association with chronic rotator cuff tendinitis
Representative population sample of Finnish adults without acute shoulder pain at baseline (Miranda et al. 2008)	Prospective / 883 persons	Clinically diagnosed chronic shoulder disorder	Repetitive movements and vibration, and especially combination of several risk factors, among women also lifting heavy loads and working in awkward postures, associated with chronic shoulder disorders
Manufacturing and health care work (Silverstein et al. 2008)	Cross-sectional / 733 workers	Clinically diagnosed rotator cuff syndrome	Increasing percent time of upper arm flexion and high hand forces (especially pinch forces) were risk factors for rotator cuff syndrome.

Irmeli Pehkonen

Evaluation and Control of Physical Load Factors at Work

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