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ABSTRACT

Musculoskeletal disorders (MSDs) are among the leading causes of disability worldwide and in Finland. Despite several national level efforts to reduce the occurrence and impact of MSDs in Finland, the prevalence of low back pain (LBP) has remained stable during the three last decades. While the epidemiologic literature has consistently implicated a common set of physical and psychosocial exposures, the magnitude of the associations varies substantially among studies. The misclassification of exposure in part reflects inconsistency in the published results. Job exposure matrices (JEM) provide systematic collections of job-related exposures, including detailed information on exposures in individual occupational titles. The use of JEMs in musculoskeletal epidemiology has been rather limited.

The overall aim of the project was to develop a tool for estimating physical and psychosocial exposures to be used in large-scale epidemiological studies on musculoskeletal disorders. The primary motivation in developing of the JEMs was to improve the precision in estimating work-related physical and psychosocial exposures. The specific aims were: (1) to construct gender-specific job exposure matrices for physical and psychosocial exposures; (2) to test the validity of the matrices; (3) to study the ability of the risk factors assessed by JEM to predict the likelihood of occurrence of low back pain; and (4) to test the practical application of the developed JEMs in the planning of rehabilitation.

We utilized two large Finnish population surveys, one to construct the JEMs and another to test the validity of the matrices. The data collection periods of both surveys were only few years apart. The exposure axis of the physical matrix included set of exposures relevant to LBP (heavy physical work, heavy lifting, awkward trunk posture and whole body vibration) and exposures that increase the biomechanical load on the low back (arm elevation) or those that in combination with other known risk factors could be related to LBP (kneeling or squatting). The exposure axis of the psychosocial matrix included job demands, job control, monotonous work, social support at work as well as job strain that was operationalized based on job demands and job control using the quadrant approach. Occupations with a similar work task and exposures profile were grouped. Exposure information was collected via face-to-face interviews. Validity of the matrix was explored by calculating the inter-method agreement between the individual-based (self-reports) and group-based

(JEM) measures. The performance of the matrices was evaluated in terms of accuracy, sensitivity, specificity and predictive ability to detect associations with low back pain. Finally, the validated matrices were pilot tested in workers with musculoskeletal diseases who participated in vocational rehabilitation.

Out of 445 Finnish occupational codes in the early 2000s the constructed matrices include 401 (90%) codes for physical exposures and 365 (82%) codes for psychosocial exposures. Overall, the validity of the physical JEM was better than the psychosocial JEM. The validity of the physical JEM was good for most of the exposures in men and for heavy physical work and kneeling or squatting in women. The psychosocial JEM showed good accuracy in identification of individuals exposed to high job strain, low job control and monotonous work, while its performance for job demands and social support was relatively low, especially in men. In men, all physical exposures assessed by JEM were statistically significantly associated with one-month prevalence of LBP. In women, four (heavy physical work, heavy lifting, kneeling or squatting and whole body vibration) out of six exposures showed an association with LBP. In both genders, three (job control, monotonous work and job strain) out of five psychosocial exposures assessed by JEM were associated with LBP. The predictive ability of the psychosocial matrix substantially improved after correction for exposure misclassification error.

The gender-specific JEM for physical exposures showed relatively high specificity without compromising sensitivity. The matrix can therefore be considered as a valid instrument for exposure assessment in large-scale epidemiological studies, when more precise but more labor-intensive methods are not feasible. Even though, the performance of the matrix for psychosocial exposures was lower as compared to the matrix for physical exposures, its performance can be substantially improved by adjustment for misclassification bias. Therefore, our results suggest that epidemiologic studies on the association between psychosocial factors at work assessed based on JEM and disease would benefit from knowing the matrix accuracy and the magnitude of exposure misclassification bias.

The matrices provide both individual exposures and exposure profiles. The matrices can be used by the social insurance system and employment offices to provide data on job-specific work requirements. The matrices may also be used vocational rehabilitation. Furthermore, they can be used to define priorities for workplace interventions and to identify high-risk target groups. Although the matrix was based on Finnish data we foresee that it could be applicable, with some modifications, in other countries with a similar occupational structure and level of technology.

TIIVISTELMÄ

Tuki- ja liikuntaelinten (TULE) sairaudet ovat mielenterveyden häiriöiden ohella merkittävin työkykyyn vaikuttava sairausryhmä Suomessa. Fyysisten ja psykososiaalisten kuormitustekijöiden yhteys TULE-sairauksiin on osoitettu useissa tutkimuksissa. Tulokset ovat kuitenkin ristiriitaisia. Yksi merkittävä syy tähän on puutteellinen altistustieto ja epätarkka altistuksen luokittelu. Työaltistematriiseilla on pyritty saamaan luotettavaa tietoa altistumisesta vaihtoehtona havainnoinnille ja haastattelutiedolle. Työaltistematriiseja on TULE-sairauksien tutkimuksessa käytetty toistaiseksi vähän. Myös käytännössä tehtävään työkykyarviointiin tarvitaan yhteismitallista ammattien kuormittavuuden arviointia.

Tutkimuksen päätavoitteena oli kehittää ammattiin perustuva työaltistematriisi tule-sairauksille, erityisesti selkäsairauksille. Erityisinä tavoitteina oli 1) työaltistematriisien laatiminen sekä fyysisille että psykososiaalisille kuormitustekijöille, erikseen miehille ja naisille 2) testata työaltistematriisien oikeellisuutta 3) verrata työaltistematriisiin perustuvien tietojen ja työntekijöiden työn kuormittavuuden itsearvioinnin kykyä ennustaa selkäkipua ja 4) testata työaltistematriisin käytännön hyödynnettävyyttä työhön paluuta tukevassa kuntoutuksessa.

Työaltistematriisien kehittämisessä hyödynnettiin kahta laajaa suomalaista väestötutkimusta (Terveys 2000, Työ ja Terveys Suomessa). Ensimmäistä aineistoa käytettiin työaltistematriisin luomiseen ja jälkimmäistä matriisin oikeellisuuden testaamiseen. Tieto kuormitustekijöistä perustui tutkimukseen osallistuneiden työntekijöiden haastatteluihin. Ammatit ryhmiteltiin Tilastokeskuksen ammattiluokituksen mukaisesti. Työaltistematriisi rakennettiin ammattinimikkeisiin perustuen liittämällä kuhunkin ammattiin siinä esiintyvät keskimääräiset fyysiset ja psykososiaaliset kuormitustekijät. Fyysinen työaltistematriisi sisälsi joukon selkäkivulle altistavia tekijöitä (raskas fyysinen työ, raskaat nostot, etukumarat asennot, koko kehon tärinä), altisteita jotka lisäävät selkään kohdistuvaa biomekaanista kuormitusta (käsien nosto hartiatason yläpuolelle) tai jotka yhdessä muiden tunnettujen riskitekijöiden kanssa voivat liittyä selkäkipuun (polvillaan tai kyykyssä työskentely). Psykososiaalisten kuormitustekijöiden työaltistematriisi koostui työn vaatimuksista ja työn hallintamahdollisuuksista, työn yksitoikkoisuudesta, sosiaalisen tuen saamisesta työssä sekä psykosisiaalisesti kuormittavasta työstä (perustuen työn vaatimusten ja hallintamahdollisuuksien suhteeseen). Työaltistematriisin validiteettia (oikeellisuutta) testattiin vertaamalla työaltistematriisin kuormitustietojen (ryhmätason tieto) ja työntekijöiden työn kuormittavuuden itsearvioinnin yhtäpitävyyttä. Luotettavuuden arvioinnissa huomioitiin työaltistematriisin tarkkuus, sensitiivisyys, spesifisyys ja kyky ennustaa alaselkäkipua. Validoituja työaltistematriiseja kokeiltiin käytännössä tule-sairauksien ammatilliseen kuntoukseen osallistuneilla työntekijöillä.

Fyysinen työaltistematriisi kattaa kaikista Suomen 2000- luvun alun 445 ammatista 401 (90%) ja psykososiaalinen työaltistematriisi 365 (82%) ammattia tai ammattiryhmää. Fyysisen työaltistematriisin validiteetti oli yleisesti ottaen parempi kuin psykososiaalisen. Miehillä useimpien fyysisten kuormitustekijöiden validiteetti oli hyvä, kun taas naisilla ainoastaan raskaan ruumiillisen työn ja polvillaan ja kyykyssä työskentelyn validiteetti osoittautui hyväksi. Psykososiaalisten kuormitustekijöiden työaltistematriisin tarkkuus oli hyvä tunnistamaan yksitoikkoisille työtehtäville, vähäiselle työn hallinnalle ja psykososiaalisesti kuormittavalle työlle altistuneet, mutta huonompi tunnistamaan suurille työn vaatimuksille ja vähäiselle sosiaaliselle tuelle altistuneet. Miehillä kaikki fyysisen työaltistematriisin altisteet olivat tilastollisesti merkitsevästi yhteydessä selkäkivun esiintyvyyten viimeisen kuukauden aikana. Naisilla neljä kuudesta altisteesta (raskas fyysinen työ, raskaat nostot, polvillaan tai kyykyssä työskentely, koko kehon tärinä) olivat yhteydessä selkäkipuun. Koko aineistossa kolme viidestä kuormitustekijästä (työn hallina, yksitoikkoine ntyö ja psykososiaalisesti kuormittava työ) olivat yhteydessä selkäkipuun. Psykososiaalisten kuormitustekijöiden työaltistematriisin ennustekyky kuitenkin parani huomattavasti kun virheluokittelusta johtuva harha korjattiin.

Fyysisten kuormitustekijöiden työaltistematriisi erikseen miehille ja naisille osoittautui suhteellisen hyväksi spesifisyydeltään vaarantamatta kuitenkaan sensitiivisyyttä. Fyysistä työaltistematriisia voidaan näinollen pitää luotettavana työkaluna altistumisen arvioinnissa laajoissa epidemiologisissa tutkimuksissa, kun muuta tarkempaa tietoa kuormitustekijöistä ei ole käytettävissä, mutta ammatti tiedetään. Vaikka psykososiaalisten kuormitustekijöiden työaltistematriisi osoittautuikin huonommaksi, sen validiteettia voidaan kuitenkin huomattavasti parantaa korjaamalla virheellisestä luokittelusta johtuvaa harhaa. Kun psykosiaalisten kuormitustekijöiden matriisia käytetään epidemiologisessa tutkimuksessa, tulosten tulkinnassa kannattaa ottaa huomioon matriisin tarkkuutta ja virheluokitusta koskeva tieto.

Työaltistematriisin soveltaminen käytännössä. Työaltiste¬matriisit antavat tietoa sekä yksittäisen työntekijän altistumisesta, mutta ne tuottavat myös kuormitusprofiileita, joita voidaan hyödyntää arvioitaessa ja kuvatessa eri ammattien kuormitusvaatimuksia työkyvyn ja kuntoutustarpeen arvioinnissa sekä kuntoutustoimenpiteiden suunnittelussa. Työaltistematriiseja voidaan hyödyntää myös työpaikkainterventioissa ja kuormitustekijöiltään korkean riskin omaavien ryhmien tunnistamisessa. Vaikka työaltistematriisit perustuvat suomalaiseen aineistoon, voidaan niiden ennakoida soveltuvan joillakin muutoksilla käytettäväksi muissakin maissa, joissa on samanlainen ammattirakenne ja teknologisen osaamisen taso.

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1 INTRODUCTION

Musculoskeletal disorders (MSDs) are among the leading causes of disability worldwide and across most regions of the world (Vos et al. 2012). They cause 21.3% of all years lived with disability (YLDs), being the second only to mental and behavioral disorders which account for 22.7% of YLDs. In Finland, MSDs are the most common cause of long-term sick leave and one of the two main causes of disability pensions, the other being mental disorders (Finnish Centre for Pensions, 2013).

Low back pain (LBP) as the most common musculoskeletal complaint has reached epidemic proportion, being reported by about 80% of people at some time in their life (WHO 2003). Worldwide, 37% of LBP was attributed to occupation (Punnett et al. 2005). Every fourth worker in Europe reports that their work causes back pain (Parent-Thiron et al. 2007).

1.1 Work-relatedness of musculoskeletal disorders

The prevalence of musculoskeletal disorders, in particular low back disorders, in certain industries and occupations is three to four times higher than in general working population (Punnett and Wegman 2004, Forcier et al. 2008, Osborne et al. 2012). High-risk sectors include nursing facilities; air transportation; mining; food processing; construction; and heavy and light manufacturing such as vehicles, furniture, appliances, electrical and electronic products, textiles, apparel and shoes (Bernard 1997, Punnett et al. 2005). Back disorders occur excessively among agricultural, construction, manufacturing, and wholesale workers, as well as among nurses and cleaners (Kaila-Kangas et al. 1999, and Viikari-Juntura 2000, Walker-Bone and Palmer 2002, Boschman et al. 2011, Osborne et al. 2012).

High physical workload, especially manual material handling, frequent bending and twisting of the trunk, and whole-body vibration, have most often been suggested as risk factors for back pain (Ratti and Pilling 1997, Hoogendoorn et al. 1999). In addition to biomechanical exposures, psychosocial factors e.g. job demands, job control, monotonous work and support at work can function either as risk factors (i.e. have both positive and negative effects on health) or modifiers of the effects of physical exposures on LBP or MSDs in general (Davis and Heaney 2000, Marras et al. 2000, Lang et al. 2012).

However, contradicting results on the role of physical workload and work-related psychosocial factors in back pain have also been reported (Burdorf A and Sorock 1997, Roffey et al. 2010, Wai et al. 2010, Lang et al. 2012). The exposure-response relationship depends on the degree to which the exposure assessment is effective in providing precise and unbiased estimates of exposure levels. A part of the contradiction is likely due to differences in the validity of exposure assessment methods and the magnitude of exposure misclassification bias. Thus, in order to more reliably estimate the effect of work-related exposures on low back pain, valid and feasible exposure assessment methods are needed. An improvement of methods of exposure assessment has become a central focus of research efforts over the past decades (Goldberg and Hémon 1993).

1.2 Assessment of physical and psychosocial occupational exposures

There is no "gold standard" method for assessment of most of the occupational exposures. Basically, two quantitative exposure assessment strategies could be differentiated: an individual-based and group-based. In an individual-based approach, exposure is assessed for each worker separately with workers' self-reports, expert observations or using direct measurements (e.g., inclinometer to measure trunk flexion or mouse use in visual display unit work).

Self-reported questionnaire as an individual-based exposure assessment method is widely used to measure both physical and psychosocial factors at work. Major limitation of this assessment method is susceptibility to reporting bias. It has been suggested that common source bias due to subjective measures of exposures increases the likelihood of false positive findings, particularly in cross-sectional studies with the self-reported health outcomes (Landsbergis et al. 2000, Lötters et al. 2003). Workers having health problems are more likely to report certain work-related exposures, particularly psychosocial exposures, than healthy workers. Such tendency might lead to differential misclassification, which results in an overestimation of the true effect (Blair et al. 2007), especially, when exposures and outcome are measured simultaneously.

In the group-based approach, subgroups of workers are constructed based on their job titles, tasks or other features of the work environment they share. In this approach, the group is the unit of analysis, not the individual. Job and industry titles are less subject to such a recall bias, but they are – if used as such – somewhat poor surrogates for generic work exposures. The group-based approach includes expert observations and job exposure matrices (JEMs).

Expert judgment of exposure. In the expert judgment approach, the occupational record of each subject is reviewed in detail to assign substance-specific exposure estimates to the job title. This method has been used to assess quantitative exposure for epidemiologic studies (Siemiatycki et al. 1989, Bouyer et al. 1995). However, it is both costly and time consuming. Its validity depends on the type of exposure, the availability of measurements to anchor estimates to specific exposures, and the quality of the experts. Expert judgments of exposure levels have often been only poorly or moderately correlated with directly measured levels (Kromhout et al. 1987, Teschke et al. 2002).

Job exposure matrix (JEM). In JEM, for a given job title or occupational group exposure level is assigned based on the group-specific average of exposure. Thus the same exposure is assign to all workers in a similar job. Such method of exposure assessment is not prone to recall bias and thus may guarantee some degree of objectivity. The external job exposure matrices are easy to apply, given the jobs in the study are coded to match the job codes in the matrix. However, the major disadvantage of such assessment method is susceptibility to non-differential misclassification of exposures, which leads to the attenuation of the observed associations towards null (Siemiatycki et al. 1989, Bouyer et al. 1995). This is due to the fact that variation of occupational exposures both within workers over time and between workers in the same job because tasks, activities, work processes, and locations change over time in workplaces is diluted in the JEMs.

1.3 Existing job exposure matrices and their use

The assessment of occupational exposures by job exposure matrices was first proposed in earlier 1980s (Hoar et al. 1980). However, the usability of earlier developed JEMs in epidemiological studies is somewhat limited, because the standard job coding systems generally group jobs into coding classes developed for econometric, not health, purposes (Coughlin and Chiazze 1990). In health research, JEMs have been first developed for chemical and microbiological exposures and were fairly successfully applied in population based studies of cancer (Hinds et al. 1985, Pannett et al. 1985, Fletcher et al. 1993, Kauppinen et al. 1993). First psychosocial job JEMs were developed in USA (Schwartz et al. 1988) and Sweden (Johnson et al. 1990). The Swedish JEM also includes some physical exposures (Johnson et al. 1990).

Up to date several psychosocial (Johnson and Stewart 1993, Kauppinen et al. 1998, Mariani 1999, Fredlund et al. 2000, Niedhammer et al. 2008, Wieclaw et al. 2008, Rijs et al. 2014) and physical JEMs (Johnson and Stewart 1993, Kauppinen et al. 1998, Mariani 1999, Fredlund et al. 2000, Rijs et al. 2014) have been developed and used in epidemiological studies.

Even though the JEM measures are more objective than self-reports, they cannot be seen as a gold standard, particularly in the context of psychosocial factors at work (Theorell and Hasselhorn 2005). Therefore, the question of the reliability of the associations between exposures, assessed by JEM and health outcomes is always warranted. However, the validity of the physical or psychosocial JEMs has rarely been examined and reported (Theorell et al. 1998, Cifuentes et al. 2007, Niedhammer et al. 2008, Wieclaw et al. 2008, Cohidon et al. 2012, Rijs et al. 2014).

1.4 Criteria for validity and performance of the job exposure matrix

The validity of a measurement method is the extent to which it measures what it is supposed to measure. Before using the measurement technique in practice, it is necessary to assess agreement of a new measurement method with the "gold standard" method or those methods that are commonly used in practice. Cohen's kappa coefficient is a generally used statistical measure of inter-rater/method agreement for categorical items (Cohen 1968). It is generally thought to be a more robust measure than simple accuracy (percent of total agreement) since kappa takes into account the agreement occurring by chance.

Evaluation of the performance of job exposure matrix comprises three main elements: accuracy of the matrix to identify exposed and non-exposed ("diagnostic accuracy"), magnitude of exposure misclassification error and ability to detect known associations between risk factors assessed by JEM and health-related outcome (Bouyer and Hémon 1993). Sensitivity and specificity are two most common indicators of the "diagnostic accuracy". Sensitivity means ability of the test to identify positive results and specificity means ability of the test to identify negative results. The JEM is optimized when the specificity is favored over sensitivity (Kromhout et al. 1992, Tielemans et al. 1998). Other indicators such as Youden's J index and likelihood ratios, which are calculated based on sensitivity and specificity are less commonly used. However, they are useful in the judgment of overall method performance.

1.5 The rationales of the present study

The present study was carried out, since the assessment of physical and psychosocial characteristics of work has presented a true challenge when assessing the associations between musculoskeletal disorders and these factors. Objective and in-depth methods, such as observations and interviews, are not often feasible, and therefore there is a great need for tools that can be used to collect work exposure information for large epidemiologic studies. JEMs present a promising source for these types of studies, since they enable systematic collections of job-related exposures, including detailed information on exposures associated with individual occupational titles. So far, however, their use of JEMs in studies of musculoskeletal disorders has been rather limited. The existing Finnish Job Exposure Matrix (FINJEM) (Kauppinen et al. 1998) has a relatively high level of confidence for the assessment of chemical and microbiological exposures, however, the physical and psychosocial dimensions of FINJEM has not been validated (Kauppinen et al. 2014).

2 STUDY OBJECTIVES

The overall aim of the project was to develop a tool for estimating physical and psychosocial exposures to be used in large-scale epidemiological studies on musculoskeletal disorders.

The specific aims were:

1. to construct gender-specific job exposure matrices for physical and psychosocial exposures

2. to test the validity of the matrices

3. to explore the ability of the risk factors assessed by JEM to predict the likelihood of occurrence of low back pain

4. to test the practical application of the developed JEMs in the planning of rehabilitation

3 MATERIALS AND METHODS

We utilized two large Finnish population samples. The Health 2000 Study (H2000) was used to construct the JEMs and the Finnish National Work and Health (FWH) Surveys to test the validity and performance of the matrices. In the current study the target population consisted of 18-64 year-old individuals, who had been working during the preceding 12 months.

3.1 Study populations

The Health 2000 Study is a large Finnish population-based study carried out in 2000–01. The main objective of the study was to obtain representative information on the current health status of the whole non-institutional adult population in Finland. The survey consisted of several questionnaires, a home interview, and a health examination. A nationally representative sample of the population was obtained using a two-stage stratified cluster sampling design. The original samples consisted of 8028 subjects aged 30 years or over and 1894 subjects aged 18–29. The participation rates were 87% and 90%, respectively. A detailed comprehensive description of the methods and processes has been published elsewhere (Aroma and Koskinen 2004, Laiho et al. 2006). The sample of this study comprised 4918 persons aged 18–64 who were working during the preceding 12 months and for whom information on occupational titles and exposures were available.

The Finnish National Work and Health Surveys have been conducted every third year since 1997 to collect information on perceived working conditions and the health of the working-age population, For the 1997-2003 Surveys, random samples of subjects aged 25-64 years independent of their working status (e.g working, unemployed, retired or student) were drawn from the Finnish population register. For the 2009 Survey a random sample of subjects aged 20-64 years was drawn from Finnish employment statistics. The sample size has varied between 2031 and 2355 persons from year to year with a response rate of 58-72% (Perkiö-Mäkelä at al. 2010). At each survey a phone number was not found for about 10-16% of subjects. The proportion of non-participants in each survey was slightly higher among men than women and among subjects aged 24-34 years than among the older subjects. Age, gender, education, socioeconomic status and occupational sector of the respondents were compared with the Census data. No major differences were found. Thus, the respondents to the FWH Surveys represent rather well the targeted population. The data from all five surveys were combined. Hence, the total number of the interviewed persons with information on occupation during 1997-2009 was 11326.

3.2 Ethical considerations

The H2000 Study, the FWH Surveys and pilot testing of practical application of the JEM in vocational rehabilitation have all obtained ethical approval from the appropriate ethics committees for research questions similar to those of this study. All data will be obtained and handled in unidentified form.

3.3 Occupational classification

In the FWH Surveys, the occupations were classified according to the Classification of Occupations 2001 by Statistics Finland. In the H2000 Study the occupations originally classified according to the Classification of Occupations 1997 by Statistics Finland were converted to the Classification of Occupations 2001. This classification is based down to the 4-digit level on the EU's classification of occupations ISCO-88(COM), which is a European version of the international classification of occupations ISCO-88 (Classification of Occupations 2001). National circumstances are taken into account by adding 5-digit occupational groups, when necessary. The Classification of Occupations 2001 includes 445 codes with 4 or 5 digits (of them 149 coded with 5-digit). The classification is based on two main concepts: type of work performed and skill. The structure of the classification is defined by skill, which are characterized by the complexity and range of the tasks and duties involved (skill level) and by the field of knowledge required, the tools and machinery used, the materials worked on or with, as well as the kinds of goods and services produced (skill specialization). In general, skill levels are bound to education. However, a corresponding skill level can also be acquired through work experience. All occupations are grouped into ten major groups. Most of the major groups (from 2 to 9) are formed on the basis of skill level, with all occupations in major groups 4 to 8 belong to the same skill level. Within these major groups occupations are divided in accordance with skill specialization. Skill level is not defined for major groups 1 (Legislators, senior officials and managers) and 0 (Armed forces).

In the Health 2000 Study, the accurate occupational codes were not available for 32 subjects and these subjects were excluded from further analyses.

3.4 Exposure information

3.4.1 Physical exposures

In the H2000 Study, exposure to physical work load was assessed through face-to-face interviews with a validated questionnaire (Viikari-Juntura et al. 1996). The respondents were asked if they were exposed (yes/no) to physical work load in their current job. The following exposures were assessed: heavy physical work, kneeling or squatting, manual lifting, carrying or pushing, working with hands above shoulder level, working in forward bent position, high hand force, repetitive movements of the hand or the wrist, keyboarding, and holding vibrating tools or driving a motor vehicle (as proxies for hand-arm vibration and whole body vibration).

In the FWH Surveys, exposure information was collected using computer-assisted telephone interviews (CATI). The following exposures were assessed using Likert-scale: physical heaviness of work, kneeling or squatting, lifting heavy loads with or without lifting devices, working with hands above shoulder level, and working in forward bent position.

The selection of physical exposures included in the matrix was based on the current knowledge of risk factors for low back disorders (heavy physical work; manual lifting, carrying or pushing; working in forward bent position and driving a motor vehicle) (Hoogendoorn et al.1999, Kuiper et al. 1999, Lötters et al. 2003). We also included exposures that increase the biomechanical load on the low back (such as arm elevation) or those that in combination with other known risk factors could be related to LBP (such as kneeling or squatting). Table 1 presents more detailed description of physical exposures assessment in the H2000 Study and FWH Surveys and their comparability.

When studying the validity of the developed JEM for physical exposures, the exposures were dichotomized. Physical heaviness of work was categorized as: 1-3 "light to moderate" and 4-5 "heavy" physical work load. Kneeling or squatting, working with hands above shoulder level, and working in forward bent position were categorized as: 1 "exposed", 2-5 "non-exposed". Lifting heavy loads with or without lifting devices was categorized as: 0-2 "no heavy lifting" and 3-4 "heavy lifting", respectively. The questions were modified from previously validated measures (Kuiper et al. 1999).

Table 1. Physical exposures assessment in the Health 2000 (H2000) Study and in the Finnish National Work and Health (FWH) Surveys.

	H2000 Study		FWH Surveys	
Exposure	Question	Response categories	Question	Response categories
Heavy physical work	Is your current job physically demanding where you need to lift or carry heavy items, to dig, shovel or pound?	yes / no	Is your work physically	1) light, 2) fairly light, 3) somewhat demanding, 4) fairly demanding, 5) very demanding
Kneeling or squatting	Does your current job involve kneeling or squatting for at least 1h/day?	yes / no	Does your work involve working on bended knee or squatted down	1) daily at least 1-2 h, 2) every day for less than 1 h, 3) almost every day, 4) occasionally, 5) not at all
Driving a motor vehicle ("Whole body vibration")	Does your current job involve driving a car, tractor or other motor vehicle for at least 4h/day?	yes / no		
Manual lifting, carrying or pushing ("Heavy lifting")	Does your current job involve manual lifting, carrying or pushing items heavier than 20 kgs at least 10 times every day?	yes / no	Do you use lifting devices when lifting heavy loads (>25 kg)	0) do not lift heavy loads at all, 1) always, 2) sometimes, 3) do not use at all, although available, 4) do not use at all, not available
Working with hands above the shoulder level ("Arm elevation")	Does your current job involve working with hands above shoulder level for at least 1h/day?	yes / no	Does your work involve holding upper limb (s) above shoulder level	1) daily at least 1-2 h, 2) every day for less than 1 h, 3) almost every day, 4) occasionally, 5) not at all
Working in a forward bent posture ("Awkward trunk posture")	Does your current job involve working in a forward bend position (while standing or kneeling) for at least 1h/day?	yes / no	Does your work involve holding your back bent forward or in awkward posture	1) daily at least 1-2 h, 2) every day for less than 1 h, 3) almost every day, 4) occasionally, 5) not at all

3.4.2 Psychosocial exposures

Information on psychosocial factors at respondents' current work was collected with questionnaires. The following psychosocial factors at work were inquired: psychological demands at work, job control, social support at work, job insecurity, threat of being bullied or mentally abused ("bullying") and quality of team work ("quality of team work").

The selection of psychosocial exposures included in the matrix was based on the current knowledge of association between psychosocial factors at work and different health-related outcomes. The selected psychosocial exposures were: job demands, job control and social support at work (Karasek and Theorell 1990).

Psychosocial exposures in the Health 2000 Study were measured with a Finnish version of the Job Content Questionnaire (JCQ) (Karasek et al. 1998). Responses were given on a five point Likert-scale from 1 (fully agree) to 5 (fully disagree).

Psychological job demands scale is the sum of the following five items: “work fast”, “work hard”, “excessive work”, “not enough time”, and “hectic job”. In the current study, Cronbach's alpha for the scale was 0.76 for men and 0.81 for women.

Job control scale is the sum of two subscales. Decision authority was measured with three items: “allows own decisions”, “decision freedom”, and “a lot of say on the job”), and skill discretion was measured with five items: “learn new things”, “requires creativity”, “high skill level”, “variety”, and “develop own abilities”. Cronbach's alpha for the scale was 0.85 for men and 0.86 for women.

Since monotonous (repetitive) work was weakly correlated with the other five items of the skill discretion scale we treated it as a separate exposure.

Social support at work was measured with four items: “support from supervisor”, “supervisor appreciates”, “support from co-workers” and “discussion on work”. Cronbach's alpha for the scale was 0.80 for men and 0.82 for women.

Job demands, job control, monotonous work and social support at work were each dichotomized using gender-specific median cut-off points in order to define low and high exposure level.

Job strain was operationalized using the quadrant approach proposed by Karasek and Theorell (1990). It defines workers who are above the median on job demands and below the median on job control as having a high strain job. Other categories are: low strain (low demands and high control), passive (low demands and low control) and active (high demands and high control). Low strain job was used as the reference category in the analyses. The job strain model is one of the most studied occupational stress models.

In the Health 2000 Study, the information on psychosocial exposures was missing for 267 (5%) persons. These subjects were excluded from further analyses related to psychosocial JEM.

3.5 Development of the job exposure matrices for studies on low back disorders

The gender-specific matrices include exposure estimates at each intersection between rows (occupational groups) and columns (physical or psychosocial exposures). The physical exposure estimates were calculated as the prevalence of exposures (percentages) in each occupational group which included at least 10 subjects in order to obtain reliable estimates. The exposure estimates for job demands, job control, monotonous work and social support at work were calculated as a median score of exposures. The job strain JEM estimate was based on JEM estimates of demands and job control and operationalized using the quadrant approach. The gender-specific estimates of exposures were obtained based on self-reported exposure data of the current occupation from the Health 2000 Study.

The occupational groups with a small number of respondents were merged based on their similarities with regard to work tasks (including supervising), work environment, and required educational level. The gender differences in the exposures were also considered. If there was no reasonable way to merge the occupation with other occupations within the gender, the exposure estimates of both genders in that occupational group were combined. The aggregation of occupational groups was made by experts.

The physical exposures were specified in quantitative (proportion of being exposed within certain occupational group) and qualitative (exposed, non-exposed) terms. If at least 50% of workers in an occupational group were exposed, then the exposure estimate was set at 1 but otherwise at 0. This cut-off point was selected since Kromhout et al. (1992) showed that JEMs are optimized when specificity is favored over sensitivity. As an alternative dichotomization, we used 40% cut-off-point to define exposed and non-exposed. The psychosocial exposures were presented as exposed or non-exposed. The dichotomization was made using gender-specific median as cut-off point.

3.6 Low back pain

In the FWH Surveys, data on low back pain were collected with an interview using the question: "Have you during the past month (30 days) had long-lasting or recurrent pain in the lumbar spine?" (yes / no).

3.7 Data analyses

The inter-method agreement between the self-reported and JEM measures of exposures was examined using accuracy and kappa. Accuracy was defined as degree of closeness of measurement to its actual value and kappa value as the chance-corrected measure of agreement between two methods. The kappa (κ) values were classified according to Cohen (1968) (<0.2 poor, 0.20-0.40 fair, 0.40-0.60 moderate, 0.60-0.80 good, and 0.80-1.00 excellent).

The performance of the matrices in the external data set was evaluated by examining the accuracy of the matrix in the identification of exposed/non-exposed individuals, estimating exposure misclassification error, and looking at the ability of the matrix to detect associations of physical and psychosocial factors at work with one-month prevalence of low back pain (predictive validity). The accuracy of the JEM was evaluated using five indicators: sensitivity (Se), specificity (Sp), Youden's J index, likelihood ratio positive (LR+) and likelihood ratio negative (LR-).

Sensitivity (Se) and specificity (Sp) were calculated as following:

$$Se = TP/(TP+FN)$$

$$Sp = TN/(FP+TN),$$

where TP - true positive, TN-true negative, FP- false positive, FN-false negative.

Both sensitivity and specificity are determine against a reference standard test ("gold standard"). Errors in measuring the sensitivity and specificity of a test will arise if the reference test itself does not have 100% sensitivity and 100% specificity. The higher the values are for sensitivity and specificity, the better is the matrix performance.

The Youden's J index has been used as a measure of the effectiveness of the JEM to discriminate between exposed and non-exposed individuals. It is calculated as $J= Se+Sp-1$. The possible range of the Youden's J index value is between 0 (totally useless) and 1 (perfect). Likelihood ratio positive is the probability of an exposed person to be classified as exposed divided by the probability of a non-exposed person to be classified as exposed. Likelihood ratio negative is the probability of an exposed person to be classified as non-exposed divided by the probability of a non-exposed person to be classified as non- exposed.

The LR+ and LR- were calculated as following:

$$LR+ = Se/(1-Sp)$$

$$LR- = (1-Se)/Sp$$

A likelihood ratio equal to 1 will indicate that the JEM measure is unable to distinguish between exposed and non-exposed. A LR > 1 will indicate that the JEM is likely to identify exposed and LR < 1 will indicate that the JEM is likely to identify non-exposed. The higher LR+ value and lower the LR- value, the better is the JEM performance.

To estimate the magnitude of exposure misclassification, biased odds ratios (OR') were calculated based on the obtained estimates of sensitivity (Se) and specificity (Sp) and assumed "true prevalence" (Pr) and "true odds ratios" (OR) using the methods described by Flegal et al. (1986). The "true prevalence" was fixed at 0.25 for heavy physical work and awkward trunk posture, at 0.20 for kneeling or squatting and heavy lifting (men), at

0.15 for arm elevation, at 0.05 for heavy lifting (women), at 0.50 for high job demands, low job control and low social support, at 0.33 for monotonous work and at 0.25 for high strain job. The “true odds ratios were fixed at two values OR=1.5, and OR=3.

Logistic regression analyses with age and year of survey adjusted odds ratios (OR) and 95% confidence intervals (CIs) were carried out to study the associations between the exposures assessed by JEM and low back pain.

Statistical analyses were performed using SAS version 9.1 and WINPEPI COMPARE2 program, version 3.08 (Abramson 2011).

4 RESULTS

4.1 Age, education and occupational structure

The age and gender distribution of the study populations matched those of the employed persons in Finland in the year 2000.

The participants of the Finnish National Work and Health Surveys were slightly older and more of them worked in private sector as compared to the Health 2000 Study participants (Table 2). In both study populations, women more often worked for local government and in non-manual occupations than men. However, proportion of women occupied in service, care and sales related occupations as well as elementary occupations was higher than men.

Table 2. Age education and occupational distribution by gender in the Health 2000 (H2000) Study and the Finnish National Work and Health (FWH) Surveys.

	H2000 Study		FWH Surveys	
	Men	Women	Men	Women
N	2 437	2 481	5 684	5 642
%	51.3	48.7	50.2	49.8
Age (mean ± SD; min, max)	41±11 (18, 64)	41±11 (18, 64)	43±10 (20, 64)	44±10 (20, 64)
Age groups (years)				
18-29	18.7	16.7	11.7	9.0
30-39	27.9	27.9	25.7	23.6
40-49	28.8	30.2	32.1	33.3
50-64	24.5	25.2	30.5	34.1

Table 2 (continued). Age education and occupational distribution by gender in the Health 2000 (H2000) Study and the Finnish National Work and Health (FWH) Surveys.

	H2000 Study		FWH Surveys	
	Men	Women	Men	Women
Employer sector				
Private	69.7	47.3	77.0	52.3
Local government	12.5	38.5	10.4	37.6
Central government	15.2	10.4	8.8	7.1
Other	2.5	3.8	3.8	2.8
Occupational groups				
Professionals	*47.4*	*59.5*	*48.0*	*58.7*
Armed forces	0.9	0.0	0.8	0.0
Corporate managers	10.0	4.4	9.5	4.6
Managers of small enterprises	5.0	2.1	3.1	1.0
Professionals	15.7	17.9	18.1	19.6
Technicians and associate professionals	13.5	21.7	13.8	20.5
Clerks	2.3	13.4	2.7	13.0
Manual workers	*52.6*	*40.5*	*52.0*	*41.3*
Service and care workers, and shop and market sales workers	4.5	22.4	5.3	23.2
Skilled agricultural and fishery workers	6.7	3.6	6.1	3.4
Craft and related trades workers	23.1	2.7	22.2	2.2
Plant and machine operators and assemblers	5.7	3.3	5.9	3.3
Drivers and related water traffic operators	6.7	0.4	7.4	0.4
Elementary occupations	5.9	8.1	5.1	8.8

4.2 Self-reported physical and psychosocial exposures

In the H2000 Study, The prevalence of all physical exposures was higher in men than in women (Figure 1). The largest gender difference was found in exposure to whole body vibration.

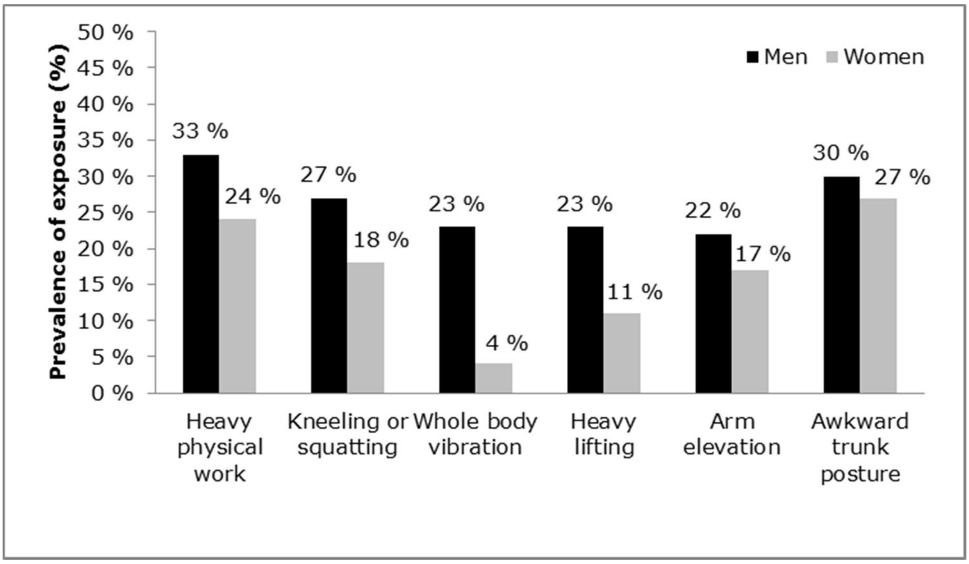

Figure 1. Prevalence of individual-based physical exposures in the Health 2000 Study by gender.

In the FWH Surveys, no gender difference in prevalence of physical exposures was observed. The prevalence of exposure to heavy physical work, heavy lifting, arm elevation, and awkward trunk posture was lower than in H2000 study than in the FWH Surveys (Figure 2).

Psychosocial exposures were dichotomized using median cut-off points. In both genders, the median values for job demands, monotonous work and social support were 3.2, 2.0 and 4.0, respectively. The median value for job control was 4.0 in men and 3.9 in women. There was no gender difference in the prevalence of psychosocial exposures (Figure 3).

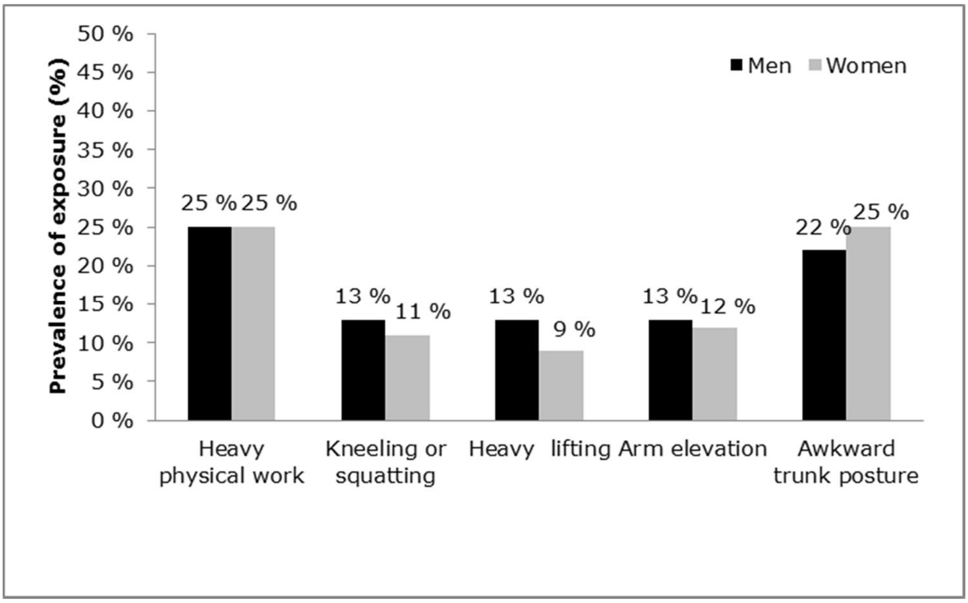

Figure 2. Prevalence of individual-based physical exposures in the Finnish National Work and Health Surveys by gender.

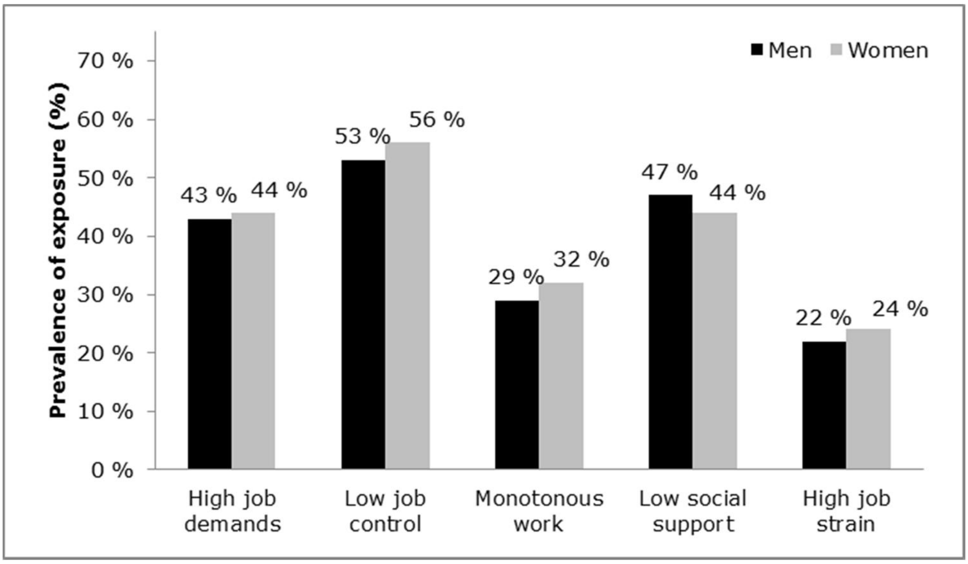

Figure 3. Prevalence of individual-based psychosocial exposures in the Health 2000 Study by gender.

4.3 Job exposure matrix

Out of 445 possible occupational codes altogether 371 (83%) were presented in H2000 Study. There were 133 occupational groups with at least 10 subjects. They covered 81.4% of the study sample. For those occupational groups that were not presented in the H2000 study, values for estimates of exposures were assigned using exposure estimate from the most similar occupational group.

4.3.1 Construction of the job exposure matrix for physical exposures

The occupational groups with a small number of respondents (< 10) were merged. In order to decide, which occupations could form a group, the exposure information was carefully reviewed by experts and groups were created based on the similarities of the work tasks (e.g. car, taxi, and van drivers and heavy truck and lorry drivers) and similarities of the exposures. Information on occupations and work tasks were collected from the literature (e.g. from scientific articles and ergonomic guidebooks) and from Internet sources (e.g. from Statistics Finland's descriptions of the occupations and job advertisements). In addition, occupations were reviewed by Finnish Institute of Occupational Health experts.

We noticed that self-employed workers had even higher risk for physical exposures than manual workers, suggesting that many of them perform regularly manual tasks. Hence, e.g. managers of small enterprises in the construction were merged, because often the main tasks of the managers are rather similar to those of workers in the company.

After merging the occupations with few respondents there were still some occupational groups with less than 10 subjects. For these groups exposure estimates were calculated using the following strategy:

1. In female- or male-dominated occupations exposure estimates for the non-dominant gender were based on the total number of respondents assuming that both genders perform similar work tasks

2. The occupational groups with similar physical exposures were merged

For 74 occupational groups, that were not present in H2000 study, exposures estimate were also assigned. Still, 44 job titles (e.g. midwives, travel attendants and travel stewards, fishery workers, hunters and trappers) could not be included in any of the occupational groups.

Selected examples of the new classification of occupations and strategy of assignment of exposure estimates are shown in Table 3.

Using the above described strategy we constructed the matrix, where for each occupational group the quantitative exposure estimate expressed as the proportion of exposed within this group was assigned. For majority of the occupational groups (n= 224, 55.9% in men and n=189, n=47.1% in women) the exposure estimates were assigned pooling responses of both genders. Nevertheless, gender-specific exposures estimates were assigned for 170 (42.4%) and 183 (45.6%) occupational groups in men and women, respectively.

We compared exposure estimates between men and women in the same occupation. The proportion of exposed to kneeling or squatting, whole body vibration, heavy lifting and awkward trunk posture tended to be higher among men than in women. The largest difference was observed for heavy lifting. However, proportion of exposed to arm elevation was higher in women than in men. Table 4 shows selected occupations with large difference in the JEM exposure estimates between men and women.

Table 3. Examples of the occupational groups and assignment strategy of physical exposure estimates.

		Men (M)		Women (W)	
Code	Occupational group	Merged occupations	Gender[1]	Merged occupations	Gender[1]
1110	Legislators and senior government officers	1110,1141,1142,1143,1210	M	1110,1141,1142,1143,1210	M+W
1141	Senior officials of political party organizations	1110,1141,1142,1143,1210	M	1110,1141,1142,1143,1210	M+W
1142	Senior officials of employers', workers' and other economic-interest organizations	1110,1141,1142,1143,1210	M	1110,1141,1142,1143,1210	M+W
1143	Senior officials of humanitarian and other special-interest organizations	1110,1141,1142,1143,1210	M	1110,1141,1142,1143,1210	M+W
1210	Directors and chief executives	1210	M	1210	M+W
1311	Managers of small enterprises in agriculture, hunting, forestry and fishing	1311, 61111, 61112, 6112	M	1311, 61111, 61112, 6112	W
61111	Field crop growers	1311, 61111, 61112, 6112	M	1311, 61111, 61112, 6112	W
61112	Field crop supervisors and workers	1311, 61111, 61112, 6112	M	1311, 61111, 61112, 6112	W
6112	Gardeners, horticultural and nursery growers and workers	6112	M	6112	W
1318	Managers of small enterprises in personal care, cleaning and related services	1318,51321,91321	M+W	1318,51321,91321	W
51321	Practical nurses	51321	W	51321	W
91321	Assistant nurses and hospital ward assistants	1318,51321,91321	M+W	1318,51321,91321	W
3222	Hygienists, health and environmental officers	3222,3412,34151,9113,6154	M+W	3222,3412,34151,9113,6154	M+W
3412	Insurance representatives	3222,3412,34151,9113,6154	M+W	3222,3412,34151,9113,6154	M+W
34151	Sales consultants and sales representatives	34151	M+W	34151	W
9113	Door-to-door and telephone salespersons	3222,3412,34151,9113	M+W	3222,3412,34151,9113	M+W
3450	Police inspectors and detectives	3450,5162,5163,5169	M	3450,5162,5163,5169	M+W
5162	Police officers	3450,5162,5163,5169	M	3450,5162,5163,5169	M+W
5163	Prison guards	3450,5162,5163,5169	M	3450,5162,5163,5169	M+W
5169	Protective services workers not elsewhere classified	5169	M+W	5169	M+W
31442	Harbor traffic controllers	31442,4133,41422,4190,9152	M	31442,4133,41422,4190,9152	W
4133	Rail traffic controllers and other transport clerks	31442,4133,41422,4190,9152	M	31442,4133,41422,4190,9152	W
41422	Porters	31442,4133,41422,4190,9152	M	31442,4133,41422,4190,9152	W
4190	Other office clerks	4190	M+W	4190	W
9152	Doorkeepers, watchpersons and related workers	31442,4133,41422,4190,9152	M	31442,4133,41422,4190,9152	W
7124	Carpenters and joiners	7124	M	(7124)	M
7129	Building frame and related trades workers not elsewhere classified	7122,7123,7124,7129	M	(7122),(7123),(7124),(7129)	M
9210	Agricultural, fishery and related laborers	9210,9311,9312,9313	M	9210,9311,9312,9313	M+W
9311	Mining and quarrying labourers	9210,9311,9312,9313	M	9210,9311,9312,9313	M+W
9312	Construction and maintenance labourers: roads, dams and similar constructions	9210,9311,9312,9313	M	9210,9311,9312,9313	M+W
9313	Building construction labourers	9210,9311,9312,9313	M	9210,9311,9312,9313	M+W

[1]Indicator of merge strategy regarding gender: M – men-specific estimates of exposure were assigned; W – women-specific estimates of exposure were assigned; M+W – men and women were merged for exposure estimates calculation.

Table 4. Examples of occupations with relatively large difference in the JEM exposure estimates between men and women.

Code	Occupational group	Proportion of espoused (%)												Merging strategy	
		HPW		K		WBV		HL		AE		AP			
		M	W	M	W	M	W	M	W	M	W	M	W	M	W
1311	Managers of small enterprises in agriculture, hunting, forestry and fishing	80.5	61.3	50.0	70.0	**81.3**	**0.0**	53.5	42.3	30.7	39.1	52.2	60.4	M	W
1314	Managers of small enterprises in wholesale and retail trade	35.9	26.8	16.5	10.9	23.0	11.7	**38.3**	**7.4**	16.8	7.9	29.7	27.5	M	W
3119	Physical and engineering science technicians	6.2	0.0	8.9	0.0	**12.0**	**33.7**	9.1	14.2	3.1	0.0	9.1	14.2	M	M+W
51331	Home care assistants	**29.1**	**59.1**	**28.9**	**50.5**	2.3	14.5	12.2	0.0	9.8	23.3	32.5	27.6	M+W	W
6130	Crop and animal producers and workers	84.1	87.7	47.3	67.6	**83.7**	**25.1**	47.6	30.8	**16.6**	**42.0**	51.1	47.0	M	W
7231	Motor-vehicle mechanics and fitters	44.4	44.01	65.9	64.8	9.1	8.7	**27.4**	**44.1**	54.6	64.8	**80.4**	**8.7**	M	M+W
8150	Chemical-processing-plant operators	44.0	56.5	**30.1**	**3.6**	5.7	3.6	42.8	9.5	24.8	16.8	49.3	34.1	M	W
9131	Domestic helpers and cleaners	**6.8**	**59.1**	0.0	50.5	**41.4**	**14.5**	12.7	0.0	**2.3**	**23.3**	**2.3**	**27.6**	M	W

HPW- heavy physical work; K -kneeling or squatting; WBV- whole body vibration; HL- heavy lifting; AE- arm elevation; AP- awkward trunk posture.

M – men-specific estimates of exposure were assigned; W – women-specific estimates of exposure were assigned; M+W – men and women were merged for exposure estimates calculation.

To construct a binary job exposures matrix we applied the following rule: if at least 50% of workers in an occupational group were exposed, then the exposure estimate was set at 1 but otherwise at 0. 298 (74.3%) occupational groups were classified as non-exposed in men and 271 (67.6%) in women. Table 5 presents the number of exposed occupations by exposure and gender.

Table 5 Number of exposed occupations by physical exposure and gender.

	Men		Women	
Exposure	No	%	No	%
Heavy physical work	63	15.7	90	22.4
Kneeling or squatting	29	7.2	38	9.5
Whole body vibration	18	4.5	11	2.7
Heavy lifting	36	9.0	29	7.2
Arm elevation	30	7.5	30	7.5
Awkward trunk posture	61	15.2	59	14.7
Any exposure	103	25.7	130	32.4

Vast majority of the occupational groups received similar exposure status in both genders. Occupations exposed to heavy physical work or kneeling or squatting were more frequently found among women than men. More occupational groups classified as exposed to whole body vibration or heavy lifting or awkward trunk posture were seen in men than in women. Tables 6 and 7 present fragment of the physical JEM for men and women.

Table 6. Fragment of the physical job exposure matrix for men.

Code	Occupational group	HPW	K	WBV	HL	AP	AE
1210	Directors and chief executives	0	0	0	0	0	0
1311	Managers of small enterprises in agriculture, hunting, forestry and fishing	1	0	1	1	1	0
1313	Managers of small enterprises in construction	1	1	0	1	1	1
41421	Mail carriers and sorting clerks	1	0	0	0	0	1
5161	Fire-fighters	1	1	1	1	0	0
6111	Field crop and vegetable growers	1	0	1	1	1	0
6130	Crop and animal producers and workers	1	0	1	0	1	0
7124	Carpenters and joiners	1	1	0	1	1	1
7141	Painters and related workers	1	1	0	1	1	1
7231	Motor-vehicle mechanics and fitters	0	1	0	0	1	1
8150	Chemical-processing-plant operators	0	0	0	0	0	0
8324	Heavy truck and lorry drivers	0	0	1	0	0	0
91322	Cleaners	1	0	0	0	0	0
9330	Transport laborers and freight handlers	1	0	0	1	0	0

HPW- heavy physical work; K -kneeling or squatting; WBV- whole body vibration; HL- heavy lifting; AE- arm elevation; AP- awkward trunk posture. 1 - exposed, 0 - non-exposed.

Table 7. Fragment of physical job exposure matrix for women.

Code	Occupational group	HPW	K	WBV	HL	AP	AE
1311	Managers of small enterprises in agriculture, hunting, forestry and fishing	1	1	0	0	1	0
1318	Managers of small enterprises in personal care, cleaning and related services	1	0	0	0	0	0
2331	Primary education teaching professionals	0	0	0	0	0	0
32261	Physiotherapists	0	0	0	0	1	0
5123	Waiters, waitresses and bartenders	0	0	0	0	1	0
51311	Childminders and kindergarten assistants	0	1	0	0	1	0
51321	Practical nurses	1	0	0	1	1	0
6111	Field crop and vegetable growers	1	1	0	0	1	0
6130	Crop and animal producers and workers	1	1	0	0	0	0
9131	Domestic helpers and cleaners	1	1	0	0	0	0
91321	Assistant nurses and hospital ward assistants	0	0	0	0	1	0
9320	Manufacturing laborers	1	0	0	0	0	0

HPW- heavy physical work; K -kneeling or squatting; WBV- whole body vibration; HL- heavy lifting; AE- arm elevation; AP- awkward trunk posture. 1 - exposed, 0 - non-exposed.

When the lower cut-off points (40%) were used to defined exposed and non-exposed occupations, 55 occupational groups were additionally classified as exposed. Table 8 shows examples of occupational groups for which exposure status has changed.

Table 8. Examples of occupational groups additionally classified as exposed when lower (40%) cut-off points were used to defined exposure status.

Code	Occupational group	HPW	K	AE	AP
1315	Managers of small enterprises of restaurants and hotels				M, W
2332	Pre-primary education teaching professionals		M, W		M, W
3141	Ships' engineers		M, W		M, W
3151	Building and fire inspectors			M, W	M, W
32311	Nurses				M, W
5122	Cooks	M, W			M, W
51326	Social work assistants		W		M, W
7232	Aircraft engine mechanics and fitters		M, W		M, W
7233	Agricultural- or industrial-machinery mechanics and fitters		M, W		M, W
91323	Kitchen helpers	M, W			M, W
9141	Building caretakers	M, W			

HPW- heavy physical work; K -kneeling or squatting; AE – arm elevation; AP- awkward trunk posture. M- in men only; W – in women only.

4.4 Construction of the job exposure matrix for psychosocial exposures

The strategy of grouping occupation with a small number of respondents was similar to that used in the construction of physical JEM: groups were created based on the similarities of the work tasks (including supervising, work with client), work environment, and required educational level and similarities of the psychosocial exposures. However, due to subjective nature of the psychosocial exposures and a larger gender differences in their perception, more effort was made to obtain a gender-specific exposure estimate. Therefore, in psychosocial JEM occupational groups were merged within the gender first and if there still was insufficient number of subjects in the group (<10), then the responses for both genders were pooled.

Such strategy was successful, for example, in grouping food manufacturing occupations (7411-7414, 8271-8278), as well as the industrial assemblers occupations (8281-8286). Some occupations were merged within one gender only, for examples, physicians and dentists were merged among men, but not among women; physicists and chemists are merged among women but not among men. For few occupations with a small number of subjects it was difficult to find another similar occupation within the gender (e.g. stock keepers), thus the responses of men and women were combined to estimate the exposure score. In addition, for 89 (34 in men and 55 in women) occupational groups, which exposure information in the H2000 was available for only one genger, gender-specific estimates were assigned using exposure estimate from the most similar occupational group.

Examples of the new occupational groups and strategy of assignment of psychosocial exposure estimates are shown in Table 9.

Table 9. Examples of the occupational groups and assignment strategy of psychosocial exposure estimates.

		Men (M)		Women (W)	
Code	Occupational group	Merged occupations	Gender[1]	Merged occupations	Gender[1]
1227	Production and operations managers in business services enterprises	1227,1232,1235,2412	M	1227,1232,1233,1234, 2412	W
22211	Senior physicians	22122,22211,22212, 22213,2222,2223	M	(22122),22211,22212, 22213,2223	W
22212	Specialists and ward physicians	22122,22211,22212, 22213,2222,2223	M	(22122),22211,22212, 22213,2223	W
22213	Other physicians (e.g. researchers)	22122,22211,22212, 22213,2222,2223	M	22213	W
22301	Matrons	22301,22302	M + W	22301,22302	W
22302	Ward sisters	22301,22302	M + W	22302	W
32311	Nurses	32311,3232,51322	M + W	32311	W
32314	Medical laboratory technologists	32314,51321	M + W	32314, 51321	W
51321	Practical nurses	32314,51321	M + W	51321	W
7121	Builders	7121	M	7121	M + W
7123	Concrete placers, concrete finishers and related workers	7121,7123, 7133	M	7121,7123,7133	M + W
7211	Metal moulders and coremakers	7211,7212,7214	M	7211,7212,7214	M + W
7212	Welders and flame cutters	7212	M	7211,7212,7214	M + W
7213	Sheet-metal workers	7213	M	7213	M + W
7214	Structural-metal preparers and erectors	7211,7212,7214	M	7211,7212,7214	M + W
7421	Wood treaters	7421,7423, 8141, 8240	M	7421,7423, 8141, 8240	M + W
7424	Basketry weavers, brush makers and related workers	7424	M	7424	M + W
7423	Woodworking machine setters and setter-operators	7421,7423, 8141, 8240	M	7421,7423, 8141, 8240	M + W
8141	Wood-processing-plant operators	7421,7423, 8141, 8240	M	7421,7423,8141, 8240	M + W
8322	Car, taxi and van drivers	8322	M	8322	M + W
8323	Bus and tram drivers	8323	M	8323	M + W
8324	Heavy truck and lorry drivers	8324	M	8324	M + W

[1]Indicator of merge strategy regarding gender: M – men-specific estimates of exposure were assigned; W – women-specific estimates of exposure were assigned; M+W – men and women were merged for exposure estimates calculation.

To construct a binary job exposures matrix the median score of psychosocial exposure for occupational group was assigned first. Second, using gender-specific median values as cut-off points, the exposure status (0- non-exposed, 1- exposed) for high job demand, low job control, monotonous work and low social support was given. Table 10 presents fragment of the psychosocial JEM for men and women.

Table 10. Fragment of the psychosocial job exposure matrix for men and women.

Code	Occupational group	Men					Women				
		HJD	LJC	MW	LSS	Strain	HJD	LJC	MW	LSS	Strain
2141	Architects, town and traffic planners	1	1	0	1	4	1	0	0	1	2
2222	Dentists	1	0	0	0	2	1	0	0	0	2
23222	Vocational and professional education institution lecturers	0	0	0	1	1	0	0	0	1	1
24702	Local government professionals	1	0	0	1	2	1	0	0	1	2
3120	Computer assistants, computer equipment operators and related associate professionals.	0	1	0	1	3	0	1	0	1	3
34151	Sales consultants and sales representatives	0	0	0	0	1	1	0	0	0	2
4131	Stock clerks	1	1	0	0	4	1	0	0	0	2
41421	Mail carriers and sorting clerks	0	1	1	1	3	0	1	1	1	3
5123	Waiters, waitresses and bartenders	1	1	1	0	4	1	1	1	0	4
7231	Motor-vehicle mechanics and fitters	0	1	0	1	3	0	0	0	1	1
7422	Cabinetmakers and related workers	0	0	0	0	1	0	0	0	0	1
8143	Papermaking-plant operators	0	1	0	0	3	0	1	1	0	3
8271	Meat- and fish-processing-machine operators	0	1	1	0	3	1	1	1	1	4

HJD = high job demand, LJC = low job control, MW= monotonous work, LSS=low social support, Strain = job strain, 1- low job strain, 2- active job, 3- passive job, 4- high job strain.

Overall, psychosocial JEM included exposure estimates for 365 occupational groups (296 in both genders, 43 in men only and 27 in women only). For 80% of the occupational groups (n= 271 in men and n=255, in women) the gender-specific exposure estimates were assigned. Only about 14% (n=49 in men and n=45 in women) of the occupational groups were classified as non-exposed to either psychosocial exposure. Occupations with high job demands or monotonous work or high strain job were more frequently found among women than men (Table 11). In contrast, there were more occupations with low job control in men than in women.

Table 11. Number of exposed occupational groups by psychosocial exposure and gender.

	Men (N=339)		Women (N=323)	
Exposure	No	%	No	%
High job demands	97	28.7	129	39.8
Low job control	178	52.5	157	48.7
Monotonous work	67	19.8	74	23.0
Low social support	165	48.8	149	46.1
High strain job	56	16.5	68	21.2
Any of the exposures	290	85.6	278	85.9

The monotonous work is an item usually included to the job control scale. In H2000 Study population it was weakly correlated with the other items of the job control scale and therefore was treated as a separate exposure. However, in the JEM 79% of the occupational groups in men exposed to monotonous work has also been classified as exposed to low job control. In women, the corresponding number was even higher (85%). Table 12 shows examples of occupational groups with similar and different exposure status for low job control and monotonous work.

Table 12. Examples of occupational groups with similar and different exposure status for low job control and monotonous work by gender.

		Men		Women	
Code	Occupational group	MW	LJC	MW	LJC
1210	Directors and chief executives	0	0	0	0
1312	Managers of small enterprises in manufacturing	0	0	1	0
1316	Managers of small enterprises in transport, storage and communications	1	1	1	0
5123	Waiters, waitresses and bartenders	1	1	1	1
51325	Dental assistants	0	1	1	1
5169	Protective services workers not elsewhere classified	0	1	0	0
52202	Salespersons and cashiers	0	1	1	1
7411	Butchers, fishmongers and related food preparers	1	1	1	1
7141	Painters and related workers	1	0	1	0
91321	Kitchen helpers	0	1	0	1

MW- monotonous work; LJC- low job control. 1 - exposed, 0 - non-exposed

More than half of the occupational groups (n=39, 58%) classified as exposed to monotonous work in men were plant, machine operators and assemblers related occupations (major occupational group 8). Although similar tendency was seen among women (n=27, 37%), 16% of the occupational groups with monotonous work were occupations related to service, care and sales (major occupational group 5).

Out of 296 occupations with exposure estimates available for both genders, 133 (45%) occupations had different exposure status for men and women in at least one of the exposures included to the matrix. We compared exposure estimates between men and women in the same occupation. The largest difference was observed for job strain, followed by social support at work. The lowest difference was seen for monotonous work. Examples of occupational groups with gender difference in the exposure status assigned by JEM are shown in Table 13.

Table 13. Examples of occupational groups with the difference between men and women in the psychosocial exposure status assigned by JEM.

		Men					Women				
Code	Occupational group	HJD	LJC	MW	LSS	Strain	HJD	LJC	MW	LSS	Strain
1210	Directors and chief executives	1	0	0	1	2	1	0	0	0	2
12299	Other production and operations managers	1	0	0	1	2	1	0	0	0	2
1231	Finance and administration managers	0	0	0	0	1	1	0	0	0	2
1233	Sales and marketing managers	0	0	0	0	1	1	0	0	0	2
1314	Managers of small enterprises in wholesale and retail trade	0	0	0	1	1	1	0	1	1	2
2131	Computer systems designers, analysts and programmers	0	0	0	0	1	0	0	0	1	1
24191	Advertising and marketing professionals	0	0	0	0	1	1	1	0	0	4
24311	Archivists	1	1	0	1	4	0	0	0	1	1
3460	Social instructors and related associate professionals	0	0	0	0	1	0	0	0	1	1
52202	Salespersons and cashiers	1	1	0	1	4	0	1	1	1	3
6130	Crop and animal producers and workers	0	0	0	1	1	0	1	1	1	3
9330	Transport laborers and freight handlers	0	1	1	1	3	1	1	1	0	4

HJD = high job demand, LJC = low job control, MW= monotonous work, LSS=low social support, Strain = job strain, 1- low job strain, 2- active job, 3- passive job, 4- high job strain.

4.5 The inter-method agreement between the self-reported and JEM measures

4.5.1 Physical JEM

In both study populations, the prevalence of binary JEM exposures was - as expected - lower than the prevalence of individual-based exposures (Figures 4 and 5). There was no difference in the prevalence of JEM exposures between the H2000 study and FWH Surveys populations. For heavy lifting, whole body vibration and arm elevation the JEM showed a considerably lower proportion of occupations being exposed, suggesting a fairly large between-worker variance of these exposures within the occupation.

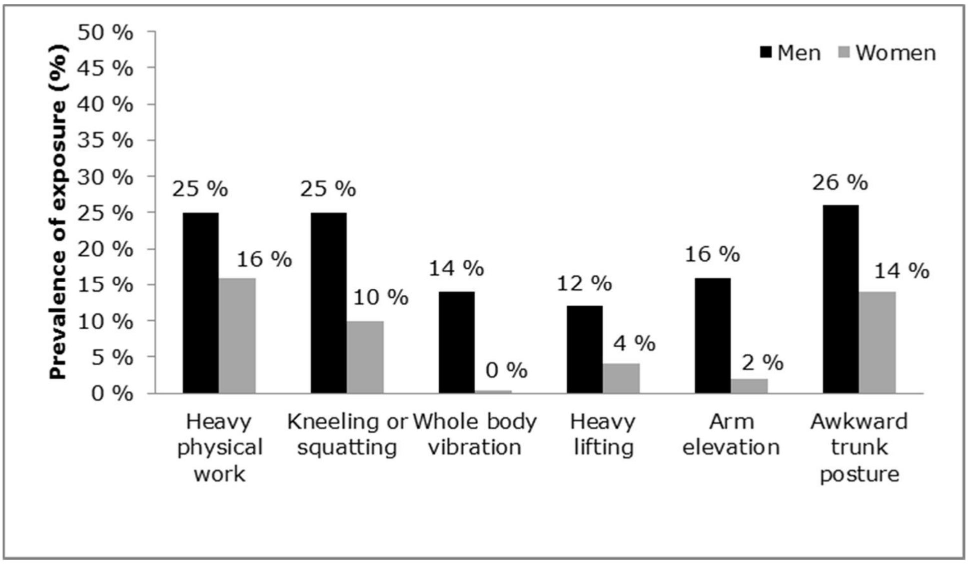

Figure 4. Prevalence of physical exposures assessed by JEM in the Health 2000 Study by gender.

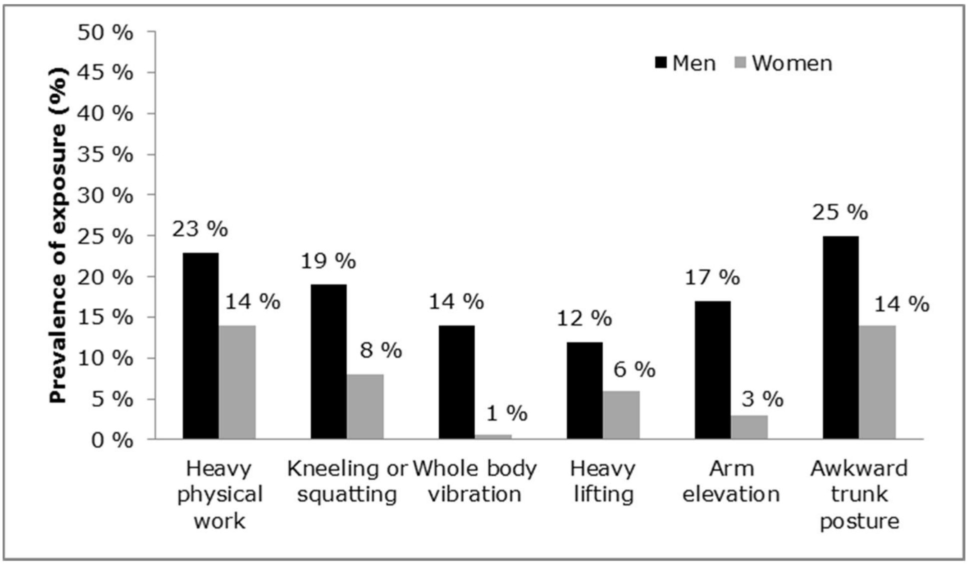

Figure 5. Prevalence of physical exposures assessed by JEM in the Finnish National Work and Health Surveys by gender.

The largest consistency of agreement was observed for whole body vibration in women with 97% of the individuals being classified similarly by both methods (Table 14). In men, the inter-method agreement assessed by kappa was moderate for four out of six exposures. The inter-method agreement for whole body vibration was good, while for heavy lifting it was fair. In women, the inter-method agreement was fair for half of the exposures. Bad inter-method agreement was observed for whole body vibration and arm elevation.

In both genders, the chance corrected inter-method agreement (κ) between individual-based exposure estimates and JEM estimates obtained with lower cut-off points (40%) has improved, especially for heavy lifting (men), kneeling or squatting (women) and arm elevation (women).

Table 14. Accuracy and kappa coefficient (κ) between individual-based and group-based measures of physical exposures for men and women in the H2000 Study.

Exposures	Men		Women	
	Accuracy	**κ**	Accuracy	**κ**
Heavy physical work	0.80	0.52	0.81	0.41
Kneeling or squatting	0.83	0.53	0.85	0.35
Whole body vibration	0.88	0.61	0.97	0.17
Heavy lifting	0.79	0.30	0.90	0.26
Arm elevation	0.84	0.48	0.84	0.16
Awkward trunk posture	0.79	0.47	0.76	0.28

4.5.2 Psychosocial JEM

In the H2000 Study the prevalence of most of JEM-based exposures was lower than the prevalence of individual-based exposures (Figure 6). The largest drop in the prevalence was observed for monotonous work (men) and job demands (both genders). There were no differences in the distribution of exposures assessed by JEM between two study populations (Figures 6 and 7).

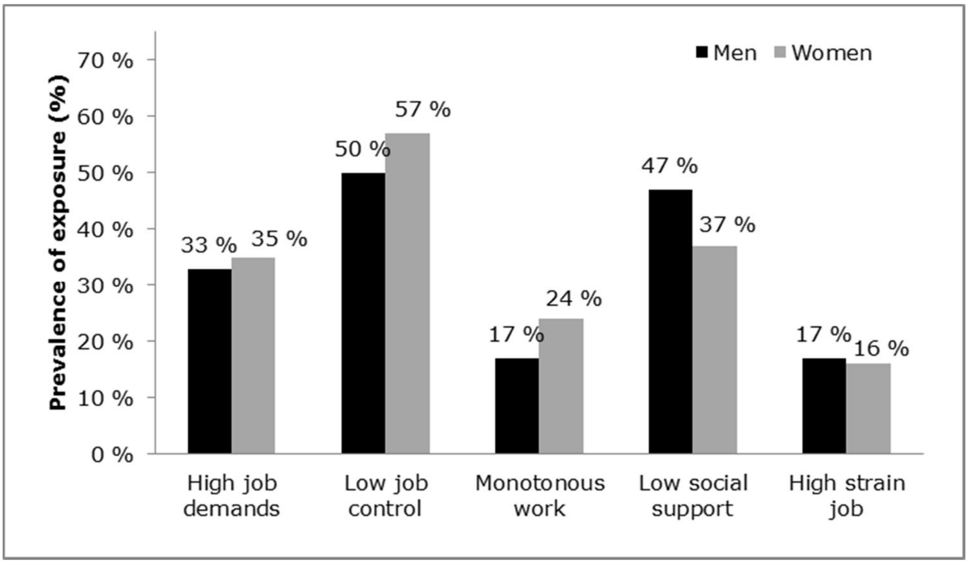

Figure 6. Prevalence of psychosocial exposures assessed by JEM in the Health 2000 Study by gender.

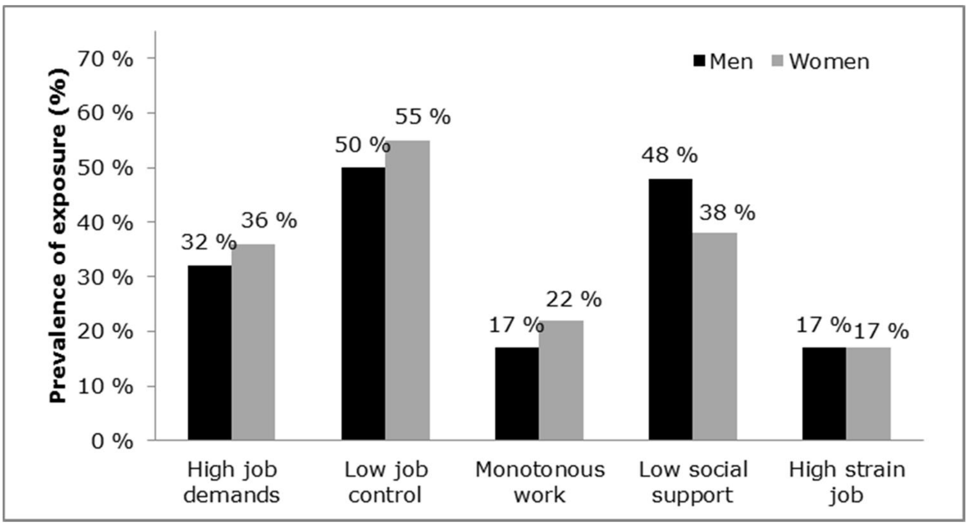

Figure 7. Prevalence of psychosocial exposures assessed by JEM in the Finnish National Work and Health Surveys by gender.

In men, the inter-method agreement between individual-based and group-based measures for psychosocial exposes was somewhat lower than that for physical exposures. In women, an opposite phenomenon was noticed. The largest consistency of agreement was observed for high strain job (women) and lowest for social support (both genders) and job demands (men) (Table 15). The inter-method agreement assessed by kappa was fair for most of the exposures in both genders. The largest kappa was observed for high strain job (both genders) and the smallest kappa was found for job demands (men).

Table 15. Accuracy and kappa coefficient (κ) between individual-based and group-based measures of psychosocial exposures for men and women in the H2000 Study.

	Men		Women	
Exposure	Accuracy	**κ**	Accuracy	**κ**
Job demands	0.61	0.18	0.64	0.24
Job control	0.68	0.36	0.72	0.43
Monotonous work	0.74	0.28	0.73	0.33
Social support	0.61	0.22	0.61	0.20
High strain job	0.74	0.46	0.82	0.64

4.6 The accuracy and misclassification error of the job exposure matrices

4.6.1 Physical JEM

In both genders, the specificity of JEM was significantly higher than sensitivity for all physical exposures (Table 16). The difference between specificity and sensitivity was larger in women than in men. JEM sensitivity for all exposures but heavy lifting has been significantly higher in women than in men. The largest specificity was found for arm elevation and heavy lifting in women. Too low sensitivity was observed for arm elevation (women) and heavy lifting (men).

Table 16. Accuracy of the physical JEM in the identification of exposed/non-exposed individuals. The Finnish National Work and Health Surveys.

Exposure		Sensitivity	Specificity	J[1]	LR+[2]	LR-[3]
Heavy physical work	Men	0.53	0.87	0.40	4.08	0.54
	Women	0.36	0.93	0.29	5.14	0.69
Kneeling or squatting	Men	0.55	0.88	0.43	4.58	0.51
	Women	0.31	0.94	0.25	5.17	0.73
Heavy lifting	Men	0.20	0.90	0.10	2.00	0.89
	Women	0.41	0.97	0.38	13.67	0.61
Arm elevation	Men	0.55	0.89	0.44	5.00	0.51
	Women	0.14	0.98	0.12	7.00	0.88
Awkward trunk posture	Men	0.53	0.84	0.37	3.31	0.56
	Women	0.29	0.90	0.19	2.90	0.79

[1]J = Youden's index; [2]LR+ = likelihood ratio positive [3]LR- = likelihood ratio negative

The physical JEM overall performance assessed by Youden's J index was better in men than in women. However, matrix significantly better differentiated between exposed and non-exposed to heavy lifting in women, than in men. The ability of the matrix to identify exposed to all physical exposures but awkward trunk posture was better in women. The matrix was not effective to identify exposed/non-exposed to heavy lifting in men and arm elevation in women. Taking to the account all three performance indicators, physical JEM performed the best for heavy lifting in women and worst for the same exposure in men.

The magnitude of misclassification error on the hypothetical effect estimates usually increases with increase in the expected true effect. In general, the magnitude of misclassification for most of the exposures did not differ between men and women (Table 17). The smallest misclassification error was observed for heavy lifting in women, while for the same exposure in men it was the highest.

Table 17. Effect of misclassification error of the physical JEM exposures on the hypothetical effect estimates.

	OR=1.5		OR=3.0	
Exposure	Men	Women	Men	Women
Heavy physical work[1]	1.20*	1.20*	1.65*	1.65*
Kneeling or squatting[2]	1.20*	1.17*	1.69*	1.59*
Heavy lifting[3]	1.07	1.19*	1.22*	1.73*
Arm elevation[4]	1.19*	1.20*	1.66*	1.66*
Awkward trunk posture[1]	1.17*	1.13	1.56*	1.40*

[1]Prevalence of exposure is assumed to equal 0.25. [2]Prevalence of exposure is assumed to equal 0.20. [3]Prevalence of exposure is assumed to equal 0.20 in men and 0.05 in women. [4]Prevalence of exposure is assumed to equal 0.15. *Statistical significance at the 5% level (two-sided test) of the biased odds ratios is calculated for a study population of 5000 men and 5000 women.

The use the 40% cut-off points to define exposure status for occupational groups, resulted in the substantial increase in matrix sensitivity for most of the exposures, especially in women (Table 18). Gain in matrix sensitive even with some loss in specificity resulted in substantial improvement of overall matrix performance and reduction of misclassification bias.

Table 18. Accuracy of the physical JEM (based on 40% cut-off points) in the identification of exposed/non-exposed individuals. The Finnish National Work and Health Surveys.

Exposure		Sensitivity	Specificity	J[1]	LR+[2]	LR-[3]
Heavy physical work	Men	0.73	0.74	0.47	2.81	0.36
	Women	0.51	0.89	0.40	4.63	0.55
Kneeling or squatting	Men	0.74	0.80	0.54	3.70	0.33
	Women	0.58	0.90	0.48	5.80	0.47
Heavy lifting	Men	0.43	0.80	0.23	2.15	0.71
	Women	0.44	0.95	0.39	8.80	0.58
Arm elevation	Men	0.55	0.88	0.43	4.58	0.51
	Women	0.20	0.96	0.16	5.00	0.83
Awkward trunk posture	Men	0.62	0.78	0.40	2.82	0.49
	Women	0.57	0.79	0.36	2.71	0.54

[1]J = Youden's index; [2]LR+ = likelihood ratio positive [3]LR- = likelihood ratio negative

4.6.2 Psychosocial JEM

The specificity of JEM measures was higher than sensitivity for all exposures but job control among women (Table 19). The matrix sensitivity was better in women than in men for all exposures. The sensitivity was the lowest for monotonous work (0.35) in men.

Overall performance of the psychosocial JEM was better in women than in men for most of the exposures. The matrix was most effective to differentiate between exposed and non-exposed to high strain job, particularly in women. The matrix was least effective to correctly identify exposed/non-exposed to high demands (men) and low support (both genders).

Table 19. Accuracy of the psychosocial JEM in the identification of exposed/non-exposed individuals. The Finnish National Work and Health Surveys.

Exposure		Sensitivity	Specificity	J[1]	LR+[2]	LR-[3]
High demands	Men	0.41	0.76	0.17	1.71	0.78
	Women	0.49	0.75	0.24	2.00	0.68
Low control	Men	0.67	0.69	0.36	2.16	0.48
	Women	0.75	0.68	0.43	2.34	0.37
High strain job	Men	0.58	0.87	0.45	4.46	0.48
	Women	0.77	0.88	0.65	6.41	0.26
Low social support	Men	0.60	0.62	0.22	1.58	0.65
	Women	0.48	0.72	0.20	1.71	0.72
Monotonous work	Men	0.35	0.90	0.25	3.50	0.72
	Women	0.46	0.86	0.32	3.29	0.63

[1]J = Youden's index; [2]LR+ = likelihood ratio positive [3]LR- = likelihood ratio negative

The largest misclassification error was observed for high demands (men) and low social support (both genders). In both genders, high strain job assessed by JEM had the smallest misclassification error (Table 20).

Table 20. Effect of misclassification error of the psychosocial JEM exposures on the hypothetical effect estimates.

	OR=1.5		OR=3.0	
Exposure	Men	Women	Men	Women
High job demands[1]	1.08	1.11	1.21*	1.28*
Low job control[1]	1.15	1.19*	1.44*	1.56*
Monotonous work[2]	1.16	1.17*	1.49*	1.52*
Low social support[1]	1.09	1.09	1.25*	1.23*
High strain job[3]	1.21*	1.29*	1.72*	2.04*

[1]Prevalence of exposure is assumed to equal 0.50.[2]Prevalence of exposure is assumed to equal 0.33. [3]Prevalence of exposure is assumed to equal 0.25. *Statistical significance at the 5% level (two-sided test) of the biased odds ratios is calculated for a study population of 5000 men and 5000 women.

4.7 Predictive validity of the constructed job exposure matrices

4.7.1 Physical JEM

In the FWH Surveys, one-month prevalence of low back pain was slightly higher among women (29%) than men (26%). Among men, associations between all physical exposures assessed by JEM and low back pain were statistically significant (Table 21). Among women, five out of six exposures were statistically significantly associated with LBP.

Table 21. Associations of the physical exposures assessed by JEM with one-month prevalence of low back pain in the Finnish National Work and Health Surveys. Odds ratios (OR) and their 95% confidence intervals (95% CI) are adjusted for age and year of survey.

	Men	Women
Exposure	OR (95% CI)	OR (95% CI)
Heavy physical work	1.59 (1.40-1.82)	1.52 (1.29-1.80)
Heavy lifting	1.60 (1.35-1.89)	1.34 (1.06-1.70)
Awkward trunk posture	1.52 (1.34-1.73)	1.18 (1.00-1.39)
Arm elevation	1.35 (1.16-1.58)	1.38 (0.99-1.91)
Kneeling or squatting	1.39 (1.20-1.60)	1.45 (1.18-1.79)
Whole body vibration	1.72 (1.21-1.66)	1.99 (1.04-3.82)

The ability of the matrix to detect association of the awkward trunk posture and kneeling or squaring with LBB in women has improved when the exposure status was defined based on lower cut-off point (Table 22).

Table 22. Associations of the physical exposures assessed by JEM (40%) with one-month prevalence of low back pain in the Finnish National Work and Health Surveys. Odds ratios (OR) and their 95% confidence intervals (95% CI) are adjusted for age and year of survey.

	Men	Women
Exposure	OR (95% CI)	OR (95% CI)
Heavy physical work	1.55 (1.38-1.75)	1.45 (1.26-1.68)
Heavy lifting	1.56 (1.37-1.78)	1.48 (1.19-1.83)
Awkward trunk posture	1.47 (1.30-1.66)	1.25 (1.10-1.42)
Arm elevation	1.34 (1.16-1.55)	1.54 (1.21-1.97)
Kneeling or squatting	1.50 (1.32-1.70)	1.38 (1.18-1.62)
Whole body vibration	1.72 (1.21-1.66)	1.99 (1.04-3.82)

4.7.2 Psychosocial JEM

Three out of five (low job control, monotonous work and high strain job) exposures assessed by JEM were statistically significantly associated with LBP in both genders (Table 23). After correction for exposure misclassification error, all JEM based exposures in men and all except high job demands in women were associated with LBP. Inverse associations between low social support assessed by JEM and LBP were observed among women.

Table 23. Associations of the psychosocial exposures assessed by JEM with one-month prevalence of low back pain in the Finnish National Work and Health Surveys. Odds ratios (OR) and their 95% confidence intervals (95% CI) are adjusted for age and survey year.

	Men		Women	
Exposure	Model 1	Model 2	Model 1	Model 2
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
High job demands	1.02 (0.91-1.16)	1.20 (1.07-1.34)	0.98 (0.87-1.11)	0.92 (0.82-1.03)
Low job control	1.24 (1.11-1.39)	1.73 (1.54-1.95)	1.26 (1.12-1.42)	1.76 (1.56-1.97)
Monotonous work	1.22 (1.05-1.42)	1.39 (1.20-1.61)	1.36 (1.19-1.55)	1.75 (1.60-1.90)
Low social support	1.07 (0.95-1.20)	1.50 (1.33-1.68)	0.98 (0.87-1.10)	0.83 (0.74-0.94)
High strain job	1.26 (1.08-1.43)	1.77 (1.51-2.09)	1.29 (1.08-1.54)	1.52 (1.27-1.81)

Model 1: ORs are adjusted for age and year of survey.

Model 2: ORs are adjusted for exposure misclassification error.

4.8 Practical application of the job exposure matrices

Use of the job exposure matrices in vocational rehabilitation of individuals with musculoskeletal problems has been discussed with rehabilitation advisors from Kiipula Rehabilitation Centre. For practical application of the developed JEMs several tables and figures in Excel were prepared. The epidemiological studies provide strong evidence that heavy lifting and awkward trunk posture are the most hazardous for low back. All occupational groups were plotted depending on the probability of these exposures. Figure 8 shows occupational distribution of heavy lifting and awkward trunk posture in craft and related trades male workers (major occupational group 7).

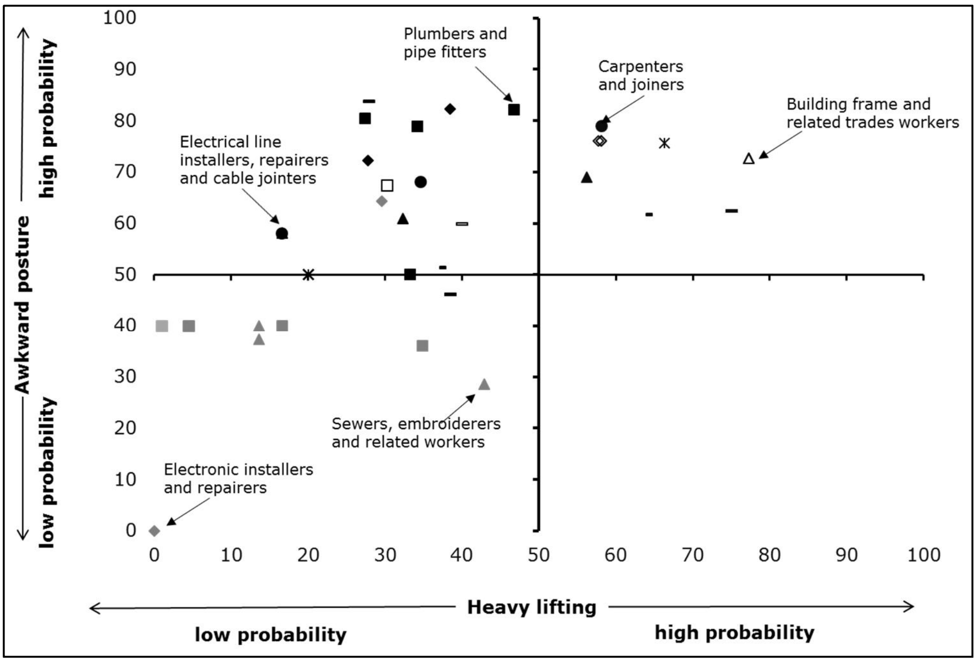

Figure 8. Occupational distribution of heavy lifting (>20 kg >10x/day) (X) and awkward trunk posture (Y) in craft and related trades male workers.

Figure 9 shows occupational distribution of heavy lifting and awkward trunk posture in clerks, service and care workers, shop and market sales workers and skilled agricultural and fishery workers female workers (major occupational groups 4,5 and 6).

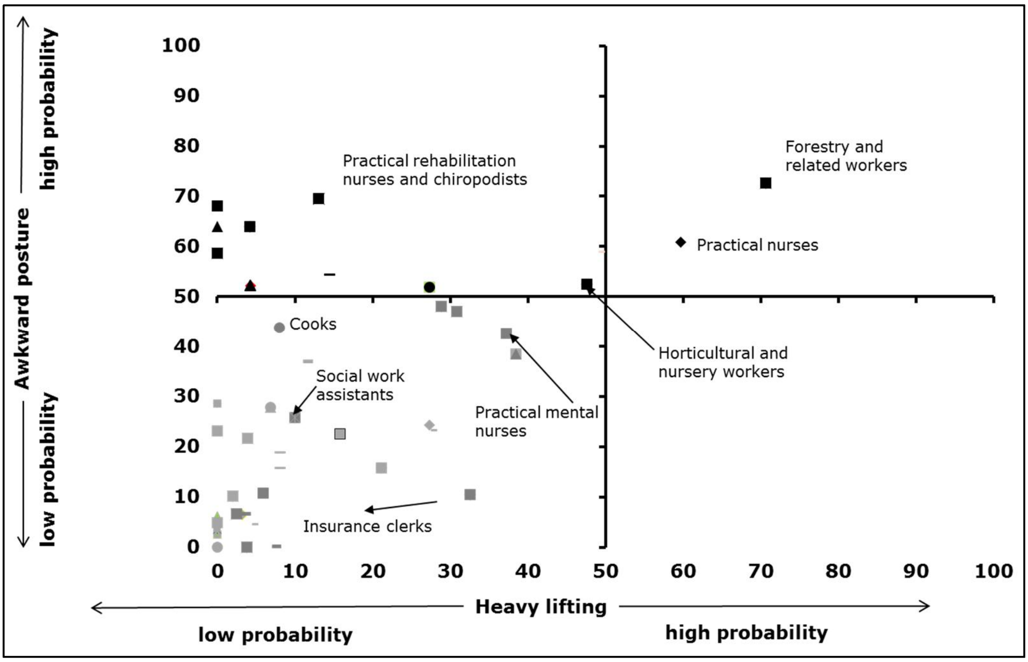

Figure 9. Occupational distribution of heavy lifting (>20 kg >10x/day) (X) and awkward trunk posture (Y) in clerks, service and care workers, shop and market sales workers and skilled agricultural and fishery workers female workers.

The validated matrices are currently pilot tested in a group of persons undergoing vocational rehabilitation. Results will be available in the fall of 2014.

5 DISCUSSION

We constructed and validated gender-specific job exposure matrices for physical and psychosocial exposures. The developed matrices are based on national data, which represent well the Finnish adult population, including the distribution of occupations. The exposure axis of the physical matrix included six exposures (heavy physical work, heavy lifting, awkward trunk posture, whole body vibration, arm elevation and kneeling or squatting) and the exposure axis of the psychosocial matrix included five exposures (high job demands, low job control, monotonous work, low social support and job strain). The occupation axis of the matrix was based on the original or merged occupational groups and included 401 occupational groups for physical JEM and 365 occupational groups for psychosocial JEM. Gender-specific exposure estimates were assigned for about 43% of the occupational groups in the physical JEM and for 80% of the occupational groups in psychosocial JEM. We used a 50% cut-off-point for the physical exposures - a common practice for constructing binary JEM - to define the exposed and the non-exposed.

Overall, the validity of the physical JEM in terms of consistency of agreement and performance indicators was better than psychosocial JEM. This was expected due to more subjective nature of psychosocial exposures, their larger between-individual variation and lower variation between different occupational groups as compared to physical exposures. The large gender difference in individual and occupational variation between physical and psychosocial exposures is reflected in the proportion of occupational groups with gender-specific exposure estimate. For these reasons more occupational groups were left out for the psychosocial than physical JEM.

The validity of the physical JEM was good for most of the exposures in men and for heavy physical work and kneeling or squatting in women. In women, the prevalence of arm elevation assessed by the JEM was low, resulting in poor performance. Lowering of the cut-off-point to 40% resulted in noticeable gain in sensitivity without a loss in specificity, especially for arm elevation. Moreover, matrix performance improved for all exposures. Hence, it could be suggested that, in case of less prevalent exposures, a lower cut-off-point could be used.

The psychosocial JEM showed a good accuracy in identification of individuals exposed to high job strain, low job control and monotonous work, while its performance for job demands and social support was relatively low, especially in men. Although several psychosocial JEMs exist, their validity is poorly explored. Our results are in line with those found for the French and Swedish psychosocial JEMs (Niedhammer et al. 2008, Fredlund et al. 2000). The relatively low inter-method agreement for job demands and social support may suggest that variation of these factors between occupations is smaller than that within occupation (Schwartz et al. 1988, Johnson and Stewart 1993). Alternatively, the poor matrix performance for social support may reflect that some psychosocial factors are highly individually oriented in that for some a particular job may be perceived as very strenuous whereas not for others in exactly the same job.

JEMs have often been criticized for potential non-differential misclassification of exposures that results in attenuation of the association between risk factor and outcome. Tielemans et al. (1998) showed that an individual-based exposure assessment generates precise though biased estimates, while a group-based assessment generates less precise but unbiased estimates. In our study, relatively large misclassification error was found for heavy lifting and job demands in men and for awkward trunk posture and social support in women. In general, the effect of non-differential exposure misclassification on the estimated odds ratios of LBP was larger for psychosocial exposures than for physical exposures, especially in men. This suggests that for the most exposures assessed by JEM only large (ORs > 3) effects of the psychosocial risk factors on health outcomes could be detected in men. Previous studies demonstrated that, the associations of JEM measures for job strain and job control with health outcomes were better reproducible than the associations for job demands (Theorell et al. 1998, Niedhammer et al. 2008, Wieclaw et al. 2008, Cohidon et al. 2012, Ropponen et al. 2013). The predictive ability of our psychosocial matrix substantially improved after correction for possible misclassification error.

6 CONCLUSIONS

The constructed gender-specific job exposure matrices for physical and psychosocial exposures were specifically designed for the use in large-scale epidemiological studies of low back disorders. However, they could also be used for other musculoskeletal disorders, e.g. neck or shoulder disorders. The matrices provide information on both individual exposures and exposure profiles.

The high specificity of physical JEM measures observed in the current study suggests that the constructed JEM can be applied to other populations as well. In general, the utility of the JEMs in epidemiological studies on the association between risk factors and disease largely depends on the accuracy of the matrix, the magnitude of exposure misclassification bias and the predictive validity of the matrix. The physical JEM has a good performance and can be utilized in epidemiological studies of MSDs, which include information about occupation but more specific exposure measures are not available. Performance of the psychosocial JEM largely depends on the degree of subjectivity some of the exposures. It performs better for exposures with relatively low individual variation within occupation and relatively large variation between occupations, e.g. job control or job strain. Our results suggest that epidemiologic studies on the association between psychosocial factors at work assessed based on JEM and disease would benefit from knowing the matrix accuracy and the magnitude of exposure misclassification bias.

7 PRACTICAL APPLICATION OF THE CONSTRUCTED JOB EXPOSURE MATRICES

The matrices can be used by the social insurance system and employment offices to provide data on job-specific work requirements. The matrices may also be used vocational rehabilitation. Furthermore, they can be used to define priorities for workplace interventions and to identify high-risk target groups. Although the matrix was based on Finnish data we foresee that it could be applicable, with some modifications, in other countries with a similar occupational structure and level of technology.

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9 REFERENCES

Abramson JH. WINPEPI updated: computer programs for epidemiologists, and their teaching potential. Epidemiol Perspect Innov 2011; 8:1.

Aromaa A and Koskinen S. Population and methods. Health and functional capacity in Finland. In: Aromaa A. and Koskinen S, editors. Baseline result of the Health 2000 Helath Examination Survey. Helsinki: The National Public Health Institute, 2004, pp. 11–23.

Bernard BP, (Ed). Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back, Department of Health and Human Services, National Institute for Occupational Safety and Health, 1997, Cincinnati, OH

Blair A, Stewart P, Lubin JH, Forastiere F. Methodological issues regarding confounding and exposure misclassification in epidemiological studies of occupational exposures. Am J Ind Med 2007; 50:199-207.

Boschman JS, van der Molen HF, Sluiter JK, Frings-Dresen MH. Occupational demands and health effects for bricklayers and construction supervisors: A systematic review. Am J Ind Med 2011; 54:55-77.

Bouyer J, Dardenne J, Hémon D. Performance of odds ratios obtained with a job-exposure matrix and individual exposure assessment with special reference to misclassification errors. Scand J Work Environ Health 1995; 21:265-71.

Bouyer J, Hémon D. Studying the performance of a job exposure matrix. Int J Epidemiol 1993; 22 (Suppl 2):S65-71.

Burdorf A and Sorock G. Positive and negative evidence of risk factors for back disorders. Scand J Work Environ Health 1997; 23:243-56.

Cifuentes M, Boyer J, Gore R, d'Errico A, Tessler J, Scollin P, Lerner D, Kriebel D, Punnett L, Slatin C; PHASE in Healthcare Research Team. Inter-method agreement between O*NET and survey measures of psychosocial exposure among healthcare industry employees. Am J Ind Med 2007; 50:545-53.

Classification of Occupations 2001. Helsinki: Statistics Finland, 2001. Handbooks / Statistics Finland, 14 (in Finnish)

Cohen J. Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychol Bull 1968; 70:213-20.

Cohidon C, Santin G, Chastang JF, Imbernon E, Niedhammer I. Psychosocial exposures at work and mental health: potential utility of a job-exposure matrix. Occup Environ Med 2012; 54:184-91.

Coughlin SS, Chiazze L Jr. Job-exposure matrices in epidemiologic research and medical surveillance. Occup Med 1990; 5:633-46.

Davis KG, Heaney CA. The relationship between psychosocial work characteristics and low back pain: underlying methodological issues. Clin Biomech (Bristol, Avon) 2000; 15:389-406.

Flegal KM, Brownie C, Haas JD. The effects of exposure misclassification on estimates of relative risk. Am J Epidemiol 1986; 123:736-51.

Fletcher AC, Engholm G, Englund A. The risk of lung cancer from asbestos among Swedish construction workers: self-reported exposure and a job exposure matrix compared. Int J Epidemiol 1993; 22 Suppl 2:S29-35.

Forcier L, Lapointe C, Lortie M, Buckle P, Kuorinka I, Lemaire J, Beaugrand S. Supermarket workers: their work and their health, particularly their self-reported musculoskeletal problems and compensable injuries. Work 2008; 30:493-510.

Fredlund P, Hallqvist J, Diderichsen F. Psychosocial job exposure matrix. An updated version of a classification system for work-related psychosocial exposure. Swedish National Institute for Working Life. Stockholm, 2000.

Goldberg M, Hémon D. Occupational epidemiology and assessment of exposure. Int J Epidemiol 1993; 22(suppl 2):S5–9.

Hinds MW, Kolonel LN, Lee J. Application of a job-exposure matrix to a case-control study of lung cancer. J Natl Cancer Inst 1985; 75:193-7.

Hoar SK, Morrison AS, Cole P, Silverman DT. An occupation and exposure linkage system for the study of occupational carcinogenesis. J Occup Med 1980; 22:722-6.

Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 1999; 25:387-403.

Johnson JV, Stewart WF. Measuring work organization exposure over the life course with a job-exposure matrix. Scand J Work Environ Health 1993; 19:21-8.

Johnson JV, Stewart WF. Fredlund P, Hall EM. Theorell T. Psychosocial job exposure matrix: an occupationally aggregated atribution system for work environment exposure characteristics. Stockhoöm: Karolinska Institute; Department of Stress Research, 1990 (Stress research report, 221).

Kaila-Kangas L, Notkola V, Keskimäki I, Mutanen P, Leino-Arjas P. Sairaalapalvelujen käyttö ammattiryhmittäin Suomessa vuonna 1996. Työterveyslaitos, Stakes, Tilastokeskus, Helsinki 1999.

Kauppinen TP, Partanen TJ, Hernberg SG, Nickels JI, Luukkonen RA, Hakulinen TR, Pukkala EI. Chemical exposures and respiratory cancer among Finnish woodworkers. Br J Ind Med 1993; 50:143-8.

Kauppinen T, Toikkanen J, Pukkala E. From cross-tabulations to multipurpose exposure information systems: a new job-exposure matrix. Am J Ind Med 1998; 33:409-17.

Kauppinen T, Uuksulainen S, Saalo A, Mäkinen I, Pukkala E. Use of the Finnish Information System on Occupational Exposure (FINJEM) in epidemiologic, surveillance, and other applications. Ann Occup Hyg 2014; 58:380-96.

Karasek RA, Theorell T. Healthy Work: Stress, Productivity, and the Reconstruction of Working Life. New York: Basic Books, 1990.

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 1998; 3:322-55.

Kromhout H, Heederik D, Dalderup LM, Kromhout D. Performance of two general job-exposure matrices in a study of lung cancer morbidity in the Zutphen cohort. Am J Epidemiol 1992; 136:698-711.

Kromhout H, Oostendorp Y, Heederik D, Boleij JS. Agreement between qualitative exposure estimates and quantitative exposure measurements. Am J Ind Med 1987;12: 551–62.

Kuiper JI, Burdorf A, Verbeek JHAM, Frings-Dresen MHW, van der Beek AJ, et al. Epidemiologic evidence on manual materials handling as a risk factor for back disorders: a systematic review. Int J Ind Ergonomics 1999; 24:389–404.

Laiho J, Djerf K, Lehtonen R. Sampling design. In: Heistaro S, editor. Methodology report Health 2000 Survey. Helsinki: the National Public Health Institute 2006; B26: 13–5.

Landsbergis P, Theorell T, Schwartz J, Greiner BA, Krause N. Measurement of psychosocial workplace exposure variables. Occup Med 2000; 15:163-88.

Lang J, Ochsmann E, Kraus T, Lang JW Psychosocial work stressors as antecedents of musculoskeletal problems: a systematic review and meta-analysis of stability-adjusted longitudinal studies. Soc Sci Med 2012; 75:1163-74.

Lötters F, Burdorf A, Kuiper J, Miedema H. Model for the work-relatedness of low-back pain. Scand J Work Environ Health 2003; 29: 431-40.

Mariani M. Replace with a database: O*NET replaces the Dictionary of Occupational Titles. Occup Outlook Quarterly 1999; 43:3-9.

Marras WS, Davis KG, Heaney CA, Maronitis AB, Allread WG. The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine. Spine 2000; 25:3045-54.

Niedhammer I, Chastang JF, Levy D, David S, Degioanni S, Theorell T. Study of the validity of a job-exposure matrix for psychosocial work factors: results from the national French SUMER survey. Int Arch Occup Environ Health 2008; 82:87-97.

Osborne A1, Blake C, Fullen BM, Meredith D, Phelan J, McNamara J, Cunningham C. Prevalence of musculoskeletal disorders among farmers: A systematic review. Am J Ind Med 2012; 55:143-58.

Pannett B, Coggon D, Acheson ED. A job-exposure matrix for use in population based studies in England and Wales. Br J Ind Med 1985; 42:777-83.

Parent-Thiron A, Fernández Macías E, Hurley J, Vermeylen G. Fourth European Working Conditions Survey. Dublin: European Foundation for the Improvement of Living and Working Conditions, 2007.

Perkiö-Mäkelä M, Hirvonen M, Elo A-L, Kauppinen K, Kauppinen T, et al. Työ ja terveys - haastattelututkimus. 2009; Helsinki: Työterveyslaitos, 2010 (in Finnish).

Punnett L, Prüss-Utün A, Nelson DI, Fingerhut MA, Leigh J, Tak S, Phillips S. Estimating the global burden of low back pain attributable to combined occupational exposures. Am J Ind Med 2005; 48:459-69.

Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol 2004; 14:13-23.

Ratti N, Pilling K. Back pain in the workplace. Br J Rheumatol 1997; 36:260-4.

Riihimäki H, Viikari-Juntura E. Back and limb disorders. In: McDonald C, Wheatley M (Eds) Epidemiology of Work Related Diseases. BMJ Books, London 2000, pp. 233-43.

Rijs KJ, van der Pas S, Geuskens GA, Cozijnsen R, Koppes LL, et al. Development and Validation of a Physical and Psychosocial Job-Exposure Matrix in Older and Retired Workers. Ann Occup Hyg 2014; 58:152-70.

Roffey DM, Wai EK, Bishop P, Kwon BK, Dagenais S. Causal assessment of awkward occupational postures and low back pain: results of a systematic review. Spine J 2010; 10:89-99.

Ropponen A, Samuelsson Å, Alexanderson K, Svedberg P. Register-based data of psychosocial working conditions and occupational groups as predictors of disability pension due to musculoskeletal diagnoses: a prospective cohort study of 24,543 Swedish twins. BMC Musculoskelet Disord 2013; 14: 268.

Schwartz JE, Pieper CF, Karasek RA. A procedure for linking psychosocial job characteristics data to health surveys. Am J Public Health 1988; 78:904-9.

Siemiatycki J, Dewar R, Richardson L. Costs and statistical power associated with five methods of collecting occupation exposure information for population-based case-control studies. Am J Epidemiol 1989; 130:1236-46.

Statistical yearbook of pensioners in Finland 2012. Official Statistics of Finland: Social protection 2013, Finnish Centre for Pensions, 2013, Helsinki. 138 p.

Teschke K, Olshan AF, Daniels JL, De Roos AJ, Parks CG, Schulz M, Vaughan TL. Occupational exposure assessment in case-control studies: opportunities for improvement. Occup Environ Med 2002; 59:575–93.

Theorell T, Hasselhorn HM. On cross-sectional questionnaire studies of relationships between psychosocial conditions at work and health--are they reliable? Int Arch Occup Environ Health 2005; 78:517-22.

Theorell T, Tsutsumi A, Hallquist J, Reuterwall C, Hogstedt C, et al. Decision latitude, job strain, and myocardial infarction: a study of working men in Stockholm. The SHEEP Study Group. Stockholm Heart epidemiology Program. Am J Public Health 1998; 88:382-8.

Tielemans E, Kupper LL, Kromhout H, Heederik D, Houba R. Individual-based and group-based occupational exposure assessment: some equations to evaluate different strategies. Ann Occup Hyg 1998; 42:115-9.

Viikari-Juntura E, Rauas S, Martikainen R, Kuosma E, Riihimäki H, et al. Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. Scand J Work Environ Health 1996; 22:251-259.

Vos T1, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380(9859):2163-96

Wai EK, Roffey DM, Bishop P, Kwon BK, Dagenais S (2010) Causal assessment of occupational lifting and low back pain: results of a systematic review. Spine J 2010; 10:554-66.

Walker-Bone K1, Palmer KT. Musculoskeletal disorders in farmers and farm workers. Occup Med (Lond) 2002; 52:441-50.

Wieclaw J, Agerbo E, Mortensen PB, Burr H, Tuchsen F, Bonde JP. Psychosocial working conditions and the risk of depression and anxiety disorders in the Danish workforce. BMC Public Health 2008; 8:280.

World Health Organization. The Burden of Musculoskeletal Conditions at the Start of New Millennium. Report of a WHO Scientific Group. WHO Technical Report Series: 919. 2003, Geneva.

The exposure-response relationship depends on the degree to which the exposure assessment is effective in providing precise and unbiased estimates of exposure levels. Objective and in-depth methods, such as observations and interviews, are not often feasible, and therefore there is a great need for tools that can be used to collect work exposure information for large epidemiologic studies.

The process of construction and validation of the gender-specific job exposure matrices for physical and psychosocial exposures is described in details. The developed matrices are based on national data, which represent well the Finnish adult population. Job exposure matrices present a promising source for epidemiologic studies, since they enable systematic collections of job-related exposures. The matrices developed in the current study can be used by the occupational health services, social insurance system, and employment offices to provide data on job-specific work requirements for assessment of work ability. At work the information provided by JEMs may help to find work tasks that match the functional capacity of the worker. The matrices may also be used in assessments for the possibilities of rehabilitation. Furthermore, they can be used to define priorities for workplace interventions and to identify high-risk target groups.

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