Original article

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Mechanical and psychosocial work exposures: the construction and evaluation of a gender-specific job exposure matrix (JEM)

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Objectives The aim of this study was to (i) construct and evaluate a gender-specific job exposure matrix (JEM) for mechanical and psychosocial work exposures and (ii) test its predictive validity for low-back pain.

Methods We utilized data from the Norwegian nationwide Survey of Living Conditions on work environment in 2006 and 2009. We classified occupations on a 4-digit level based on the Norwegian version of the International Standard Classification of Occupations (ISCO-88). The mechanical and psychosocial exposure information was collected by personal telephone interviews and included exposures that were known risk factors for low-back pain. We evaluated the agreement between the individual- and JEM-based exposure estimates, with kappa, sensitivity and specificity measures. We assessed the JEM's predictive validity by testing the associations between low-back pain and the individual- and JEM-based exposure.

Results The results showed an overall fair-to-moderate agreement between the constructed JEM and individual work exposures. The JEM performed considerably better for mechanical work exposures compared with psychosocial work exposures. The predictive validity of the mechanical and psychosocial JEM showed a consistently lower but predominantly reproducible association with low-back pain for both genders.

Conclusions The mechanical estimates and psychosocial stressors, such as psychological demands, monotonous work and decision latitude in the constructed JEM, may be useful in large epidemiological register studies. The predictive validity of the matrix was evaluated as being overall acceptable;it can thus be an effective and versatile approach to estimate the relationship between work exposures and low-back pain.

Key terms aggregated exposure estimate; back pain; low-back pain; mechanical work exposure; occupational group; pain; physical exposure; validation; workload.

Musculoskeletal disorders remain the leading diagnoses behind sickness absence across Europe (1). In 2016, 31% of all cases of sickness absence in Norway had a musculoskeletal diagnosis, with symptoms from the low back the most prevalent (2). In occupational research, considerable attention has been focused on identifying risk factors for work-related low-back pain, acknowledging the multifactorial etiology and the importance of both mechanical and psychosocial work exposures (3–18). However, the high prevalence of low-back pain in society has led to controversies and discussion on the role of occupational exposure (19), highlighting the continued need for high quality studies on the association between work exposures and low-back pain.

The Nordic countries have a longstanding tradition of establishing national registers, and their availability for research purposes has increased in recent years. However, most registers are not designed for a specific research purpose and usually lack information on occupational exposures. This has led to an increasing interest in group-based exposure estimation using job exposure matrices (JEM). During the last few years, several JEM for mechanical and psychosocial work factors have been constructed (20–27), but they have rarely taken into account possible gender differences in exposure levels between men and women with the same job titles (28). Gender differences in low-back pain prevalence may also suggest that there are differences in exposure or that women and men are strained differently doing the same task (29). Thus, gender-specific group-based exposure levels may be of importance to increase accuracy in the exposure estimates. Furthermore, the rapid changes in

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working life, such as the introduction of new technology leading largely to automatic equipment in manufacturing occupations, suggest that JEM must be updated and constructed based on new occupational titles and tasks. This underlines the motivation and necessity of this study, the aim of which was to (i) construct a JEM for mechanical and psychosocial work exposures, (ii) evaluate its agreement with individual exposures, and (iii) test its predictive validity for low-back pain.

Methods

Study population

To determine the mechanical and psychosocial work exposures by occupational group, data from the Norwegian nationwide Survey of Living Conditions on work environment were used. Statistics Norway (SSB) conducted this panel survey by personal telephone interviews (0.5% of the interviews were face to face). Eligible respondents were Norwegian residents aged 18–66 years, and samples were randomly drawn from this population at two time points, in 2006 (sample N=12 550, response rate 67%) and 2009 (sample N= 12 255, response rate 61%); a total of 6700 participants answered both in 2006 and 2009. Comparisons of the samples to the gross population according to age, gender and region showed no major differences (30). The target population in the current study was Norwegian residents aged 18–66 years who were in paid work during the reference week or temporarily absent from such work. This resulted in a total of 19 236 interviews containing information on occupation and work exposure, (9963 interviews September 2006–February 2007 and 9273 June 2009–January 2010). See table 1 for background characteristics of the study population.

Occupation

Data on occupation was self-reported and coded by SSB according to the Norwegian Standard (STYRK-98), which is based on the International Standard Classification of Occupations (ISCO-88), which is one of the main international classifications for which ILO is responsible. This classification has hierarchical categories on different digit-levels (1-digit level = 10 different occupational fields (eg, code 2 = professionals), 2-digit level = 31 occupational areas (eg, code 22 = life science and health professionals), 3-digit level = 108 occupational groups (eg, code 222 = health professionals) and 4-digit level = 353 occupations (eg, code 2221 = medical doctors). In the current study, we used occupational groups on a 4-digit level. Of the 353 different occupations at 4-digit level in STYRK 1998, 330 occupational titles (93%) were available in our study sample.

Table 1a. Background characteristics of the study population and job exposure matrix group characteristics.

Variables (individual level)	All (N=18 939)		Women (N=9 062)		Men (N=9 877)	
	N	%	N	%	N	%
Age (years)						
18–24	1908	10	936	10	972	10
25–44	8679	46	4244	47	4435	45
45–66	8352	44	3882	43	4470	45
Educational level						
Basic school level	2181	12	962	10	1219	13
Upper secondary education	9301	49	4130	46	5171	52
College/university 4 years	5298	28	3074	34	2224	23
College/university >4 years	1794	9	715	8	1079	11
Missing	365	2	181	2	184	2
Major occupational categories (STYRK-98)						
Legislator, senior officials and mangers	1874	10	564	6.2	1310	13
Professionals	2827	15	1348	14.9	1479	15
Technicians and associate professionals	5071	27	2778	30.6	2293	22
Clerks	1194	6	758	8.4	436	5
Service workers and shop and market sales workers	3915	21	2851	31.5	1064	11
Skilled agricultural and fishery workers	417	2	78	0.8	339	3
Craft and related trade workers	1869	10	131	1.4	1738	18
Plant and machine operators and assemblers	1169	6	147	1.6	1022	10
Elementary occupations	596	3	407	4.5	189	2
Armed forces	0	0	0	0.0	0	0
Missing	7	0	0	0.0	7	0.1
Low-back pain (previous month)						
Severely/somewhat	6626	35	3437	38	3189	32
A little/not at all	12 269	64	5601	61	6668	67
Missing	44	0.2	24	0.3	20	0.2

Table 1b.

Occupational groups	All (N=330)		Women (N=268)		Men (N=303)	
	N	%	N	%	N	%
Respondents per occupational title						
1–18	148	45	190	71	164	54
≥19	182	55	78	29	139	46

Table 1c.

JEM groups	All (N=268)		Women (N=195)		Men (N=209)	
	N	%	N	%	N	%
Gender-specific groups						
Unmerged	108	40	48	24	60	29
Merged	24	9	11	6	13	6
Combined gender groups						
Unmerged	84	31	84	43	84	40
Merged	52	20	52	27	52	25

Mechanical work exposure

Self-reported mechanical workload was measured using items developed by an expert group in a Nordic cooperation project (31). The respondents were asked if

they were exposed to eight different mechanical work exposures: (i) heavy lifting, (ii) neck flexion, (iii) hands above shoulder height, (iv) squatting/kneeling, (v) forward bending, (vi) awkward lifting, (vii) heavy physical work and (viii) standing/walking. "Yes" responders were asked to estimate the proportion of the working day they were exposed. A description of questions and response categories are reported in table S1 (www.sjweh.fi/show_abstract.php?abstract_id=3774).

Psychosocial work exposure

Self-reported psychosocial work exposures were measured with items developed by SSB (30) and from the General Nordic questionnaire for psychological and social factors at work (QPS_{Nordic}) (32). The five psychosocial exposure dimensions included were: (i) psychological demands, consisting of three dimensions: quantitative demands, role conflict and emotional demands; (ii) decision latitude, consisting of two dimensions: decision authority and skill discretion; (iii) job strain constructed by combining psychological demands and decision latitude; (iv) monotonous work measured by a single item; and (v) supportive leadership measured with three items. (See table S1.)

Low-back pain

The low-back pain data were collected by self-reported information: "Have you over the past month been afflicted by pain in the lower part of the back?". The question had four response categories: severely, somewhat, a little, or not at all, which were dichotomized into pain cases (severely or somewhat afflicted) and non-cases (afflicted a little or not at all).

Construction of the job exposure matrix (JEM)

The matrix developed in this study was gender-specific, with group-based exposure estimates at each intersection between the occupations (rows) and the eight mechanical and five psychosocial work exposures (columns). In order to achieve reliable estimates and be well within the recommended respondent number in each group (33), we decided to have ≥19 respondents with the same occupational code when constructing the JEM groups. Two authors grouped the occupations and further discussed with another author and two other experts at the Norwegian Institute of Occupational Health. If gender-specific occupational groups were not achieved, a combined exposure estimate for men and women in the same occupation was made.

Individual exposure estimation. The individual exposure levels for each of the eight mechanical exposures were dichotomized based on the scientific literature (34). For example, awkward lifting is regarded as strenuous on the low back even with short duration of exposure (4) and therefore dichotomized into exposure: No (no or very little of the workday) or Yes (≥¼ of the work day). The same dichotomization was used for exposure to neck flexion, hands above shoulder height, squatting/kneeling, and heavy physical work. Standing/walking needs longer duration of exposure to be considered strenuous on the low back and was therefore dichotomized into: No (≤¼ of the work day) or Yes (≥½ of the work day). Heavy lifting (lifting >20 kg) was dichotomized into exposure: No (no or very little of the workday) or Yes (1–≥4 times). The individual levels for the five psychosocial exposures were more difficult to dichotomize and were therefore calculated in the same way as in a previous study (23), ie, by splitting the indexes at the median.

Group-based exposure estimation (JEM). When modeling the JEM exposure, we chose an average exposure estimation where we calculated the JEM exposure score for each of the eight mechanical and five psychosocial work exposures as the mean of the dichotomized individual score in each occupational group (0–100%). When testing the agreement between the JEM and the individual exposures, the mean scores of the mechanical exposure in each occupational group was dichotomized and cut-off levels of 20, 30, 40 and 50% were tested. The mean score of the psychosocial exposure in each occupational group was dichotomized and a median and upper tertile cut-off level were tested. We chose the individual cut-off levels based on the exposure distribution and the performance indicators (kappa, sensitivity and specificity), favoring specificity as recommended by Tielemans et al (35).

Assessment of the JEM performance

We used four performance indicators to evaluate the JEM (ie, comparing the group-based exposure estimates with the individual-based exposure estimates): kappa, sensitivity, specificity and AUC (ie, the area under the receiver operating characteristics (ROC) curve). The Cohen's kappa coefficient (κ) measures agreement and takes into account that agreement may occur by chance. We classified the kappa values according to Cohen, as follows: poor (<0.20), fair (0.21–0.40), moderate (0.41–0.60), good (0.61–0.80) and excellent (0.81–1) agreement (36). *Sensitivity* measures the proportion of the exposed subjects in the individual-based estimates that are identified as exposed in the group-based estimates. *Specificity* measures the proportion of unexposed subjects in the individual-based estimates that are identified as unexposed in the group-based estimates. AUC measures the JEM`s ability to classify exposed and non-exposed individuals and plots the sensitivity against the specificity for the exposure

estimates. We classified the AUC values as follows: fail (0.50–0.60), poor (0.60–0.70), fair (0.70–0.80), good (0.80–0.90) and excellent (0.90–1). The ROC curve can also be used to see the tradeoff between sensitivity and specificity for the different exposures. Kappa, sensitivity, specificity and AUC were estimated using different cut-off points in the dichotomization of the exposure estimates on a group level (20%, 30%, 40% and 50% for mechanical work factors and median and the upper tertile for psychosocial work factors). The cut-off point giving the highest values for the four agreement measures was chosen to optimize the JEM performance. We estimated the explained variance R^2, which quantifies the proportion of the variance in the individual exposure estimates that was explained by the constructed JEM groups. We also estimated the theoretical magnitude of exposure misclassification for some of the exposures that showed low specificity by calculating biased odds ratios (OR_{bias}) based on our obtained sensitivity and specificity levels and the true prevalence and true OR (OR_{true} using the formula proposed by Flegal (37). The true prevalence was fixed at 50% and the OR_{true} was fixed at 1.5. The relative difference between the OR_{bias} and OR_{true} was estimated as follows: (OR_{bias} - OR_{true}) / OR_{true}. Finally, we tested the predictive validity of the present JEM for low-back pain by comparing the association between the JEM- and individual-based exposure estimates, respectively, and low-back pain. The associations were tested using logistic regression with calculated OR and corresponding confidence intervals (CI). We stratified by gender and adjusted for age. All analyses were done using Stata, version 14.0 (Stata Corp, College Station, TX, USA).

Results

Of the 330 job titles available in our sample, we ended up with a total of 268 occupational groups in our JEM; 192 occupational titles were kept unmerged (108 of them were gender-specific) and 76 occupational groups were made by merging occupational titles with similar exposure (24 of them were gender-specific). More information on JEM group characteristics and the matrix construction is found in table 1 and table S2 (www.sjweh.fi/show_abstract.php?abstract_id=3774), respectively.

Evaluation of different exposure cut-off levels

The estimates of the JEM performance regarding kappa agreement, sensitivity, specificity and AUC, testing different cut-off levels for exposures, are found in table S3 (www.sjweh.fi/show_abstract.php?abstract_id=3774),. For mechanical exposures, except for the most prevalent one (standing/walking), all performance indicators improved when lowering cut-off levels from 50% to 30 and 20%. Using a high cut-off level (50%) on the highly prevalent exposures and a lower cut-off level (30 or 20%) on the less prevalent exposures, resulted in a matrix with high specificity in both genders (>80% for most exposures). Using a median cut-off level for the psychosocial work exposures showed a better JEM performance for agreement compared with using the upper tertile cut-off, with a high specificity in men (>70% for four of the five exposures), but somewhat lower among women (specificity >70% for only two exposures). For the mechanical exposures, we used a 20% cut-off level for exposures to heavy lifting, hands above shoulder height and heavy physical work in the constructed JEM. For exposures to neck flexion, squatting/kneeling, forward bending and awkward lifting, a cut-off level of 30% was chosen, while for standing/walking, a cut of level of 50% was used. For the psychosocial exposures, we used a median cut-off level in the constructed JEM.

The performance of the constructed JEM

The performance of the constructed JEM, considering agreement with individual exposures, is presented in table 2. For mechanical work exposures, the kappa ranged from fair for neck flexion (0.22 in women and 0.23 in men) to good and moderate for women and men, respectively (0.59 and 0.68). The sensitivity was >50% in three of the eight exposures among women and in five of the eight exposures in men, and specificity was >80% in seven of eight exposures among women and six of the eight among men. For psychosocial work exposures, the kappa agreement was mostly fair, ranging from poor for supportive leadership (0.11 in both women and men) to fair for psychological demands in women (0.38) and monotonous work in men (0.32). The sensitivity was >50% in all five exposures among women and in four of the five exposures in men, and the specificity was <80% for all five exposures for both women and men.

The performance of the constructed JEM, considering the explained variance (R^2), is presented in table 2. For mechanical work exposures, the amount of variation in individual exposures explained by the JEM groups ranged from 7% (heavy lifting) to 35% (standing/walking) in women and from 13% (neck flexion) to 41% (standing/walking) in men. For psychosocial work exposures, the amount of variation in individual exposures explained by the JEM groups ranged from 1% (supportive leadership) to 14% (psychological demands and monotonous work) in women and from 1% (supportive leadership) to 10% (monotonous work) in men.

Predictive validity of the constructed JEM

Statistically significant associations between all eight

Table 2. Agreement measures between individual- and group-based work exposures using different cut-off levels on exposure, by gender. [AUC=area under the receiver operating characteristics (ROC) curve; ExpG=exposed group; ExpI=exposed individual.]

Work exposure	Cut-off % [a]	Women							Men						
		Kappa	Sensitivity %	Specificity %	AUC	Exp G %	Expl %	R^{2} [b] %	Kappa	Sensitivity %	Specificity %	AUC	Exp G %	Expl %	R^{2} [b] %
Mechanical exposure															
Heavy lifting (>20 kg)	20	0.27	58	86	0.72	17	16	7	0.35	66	79	0.73	28	7	26
Hands above shoulder height	20	0.25	50	84	0.67	20	17	18	0.42	74	80	0.77	29	12	29
Heavy physical work	20	0.23	46	84	0.65	20	19	17	0.34	77	71	0.74	38	12	29
Squatting/kneeling	30	0.34	52	86	0.69	20	18	15	0.51	66	89	0.77	21	16	32
Work with neck flexion	30	0.22	42	81	0.61	25	21	10	0.23	41	83	0.62	23	25	13
Forward bending	30	0.25	32	91	0.62	12	12	17	0.30	37	92	0.65	12	14	21
Awkward lifting	30	0.29	46	86	0.66	19	13	17	0.28	37	91	0.64	13	15	27
Standing/Walking	50	0.68	90	78	0.84	59	44	35	0.59	78	81	0.80	45	54	41
Psychosocial exposure															
High psychological demands	Median	0.38	69	69	0.69	56	56	14	0.28	52	76	0.64	38	48	8
Low decision latitude	Median	0.24	79	44	0.61	68	55	6	0.26	49	77	0.63	34	42	7
High job strain	Median	0.28	53	76	0.64	33	32	8	0.19	53	76	0.58	11	20	4
Low supportive leadership	Median	0.11	57	54	0.56	50	45	1	0.11	55	57	0.55	48	47	1
High monotonous work	Median	0.37	65	73	0.68	42	41	14	0.32	56	75	0.65	37	40	10

[a] We chose the individual cut-off levels based on the exposure distribution and the performance indicators (kappa, sensitivity and specificity), favoring specificity as recommended by Tielemans et al (35). The mean scores of the mechanical exposure in each occupational group was dichotomized and cut-off levels of 20%, 30%, 40% and 50% were tested. The mean score of the psychosocial exposure in each occupational group was dichotomized and a median and upper tertile cut-off level were tested.

[b] Explained variance in exposure (R^2) as an indicator of the amount of variance in the individual based exposure estimate that is explained by the occupational groups (JEM groups).

individual assessed mechanical work exposures and low-back pain were observed among both women (OR ranging from 1.4−2.0) and men (OR ranging from 1.6−2.2) (table 3). The OR were reduced but remained statistically significant when using JEM-based mechanical exposures, the largest reduction was found for heavy physical work among women (26%) and awkward lifting among men (36%). For psychosocial work exposures, individual assessed low decision latitude, high job strain and high monotonous work showed significant associations with low-back pain among both women and men (OR ranging from 1.3−1.6 and 1.6−1.7, respectively) (table 4). We found a reduction in the associations when using JEM-based psychosocial exposures, with the largest percentage change in monotonous work for women (33%) and job strain for men (50%). The constructed JEM did not replicate the significant individual level associations between low back pain and exposure to monotonous work among women and job strain for both genders at the. Our attempt to quantify the size of possible misclassification error in the JEM exposures showed that for mechanical work exposures, OR_{bias} was 20% lower than the true estimate for heavy physical work among men and 12% lower for standing/walking work among women (not shown). Our analysis also showed highest misclassification in psychosocial work exposures, where OR_{bias} was 33% lower for supportive leadership among men and 27% lower than the true estimate for job strain for both genders.

Discussion

The results from this large, representative nationwide study generally show fair-to-moderate agreement between the constructed JEM and individual work exposures. The predictive validity of the JEM showed consistently lower, but predominantly reproducible associations between mechanical and psychosocial exposures and low-back pain for both genders. The JEM performed considerably better for mechanical work exposures compared with psychosocial work exposures and the JEM for mechanical work exposures performed better for men than women.

Our results show that JEM-based mechanical workload for occupational titles, assessed by population-based surveys can be useful as conservative proxies for individual data in large epidemiological studies lacking exposure data. This is in accordance with similar studies from Denmark (25) and Finland (22). Our constructed JEM on mechanical workload showed an overall fair-to-moderate agreement, which is identical with findings in a Danish constructed expert-based matrix (25). The Danish JEM was, however, not gender-specific. In Finland, they constructed a gender-specific JEM based on six dimensions of mechanical workload assessed by a population-based survey and found, similarly to us, that the kappa values were better among men than women (22). Their JEM also showed, in the same man-

Table 3. Individual and job exposure (JEM)-based associations between mechanical work exposures using individual and group estimates and low-back pain the last month (adjusted for age). [OR=odds ratio; CI=confidence interval.]

Mechanical work exposure	Women			Men		
	OR	95% CI	% change [a]	OR	95% CI	% change [a]
Heavy lifting (>20 kg)						
Individual	1.6	1.3–1.9		1.7	1.5–1.9	
JEM	1.4	1.3–1.6	13	1.4	1.3–1.6	18
Work with neck flexion						
Individual	1.5	1.3–1.7		1.6	1.5–1.8	
JEM	1.3	1.2–1.5	13	1.4	1.3–1.5	13
Hands above shoulder height						
Individual	1.3	1.2–1.6		1.6	1.4–1.8	
JEM	1.2	1.1–1.3	8	1.4	1.3–1.5	13
Squatting/kneeling						
Individual	1.8	1.6–2.0		1.7	1.5–1.8	
JEM	1.4	1.2–1.6	22	1.4	1.3–1.6	18
Forward bending						
Individual	1.7	1.4–1.9		1.8	1.6–2.1	
JEM	1.4	1.2–1.6	18	1.4	1.2–1.6	22
Awkward lifting						
Individual	1.9	1.7–2.2		2.2	1.4–2.4	
JEM	1.5	1.3–1.7	21	1.4	1.3–1.6	36
Heavy physical work						
Individual	1.9	1.7–2.1		1.9	1.7–2.1	
JEM	1.4	1.2–1.5	26	1.5	1.4–1.6	21
Standing/Walking						
Individual	1.4	1.3–1.5		1.6	1.4–1.7	
JEM	1.4	1.3–1.5	0	1.4	1.3–1.5	13

[a] Change in OR based on JEM exposures and OR based on individual exposures.

Table 4. Individual and job exposure (JEM)-based associations between psychosocial work exposures using individual- and group estimates and low back pain the last month (adjusted for age). [OR=odds ratio; CI=confidence interval.]

Psychosocial work exposure	Women			Men		
	OR	95% CI	% change [a]	OR	95% CI	% change [a]
High psychological demands						
Individual	1.2	0.9–1.5		1.3	0.9–1.7	
JEM	1.0	0.9–1.1	17	0.7	0.5–0.9	46
Low decision latitude						
Individual	1.3	1.0–1.6		1.6	1.2–2.1	
JEM	1.5	1.2–2.0	–15	1.4	1.1–1.8	13
High job strain						
Individual	1.4	1.1–1.7		1.8	1.3–2.3	
JEM	1.2	1.0–1.9	14	0.9	0.6–1.5	50
Low supportive leadership						
Individual	1.0	0.8–1.3		1.3	0.9–1.6	
JEM	1.0	0.9–1.1	0	1.3	0.9–1.7	0
High monotonous work						
Individual	1.6	1.3–2.0		1.6	1.2–2.1	
JEM	1.2	0.9–1.5	25	1.9	1.4–2.5	-18

[a] Change in OR based on JEM exposures and OR based on individual exposures.

ner as our constructed JEM, specificities mainly >80% in both genders, indicating a good ability to identify the unexposed individuals. The mechanical exposures based on our JEM explained between 7–41% of the variance of the individual based exposures, this is considerably lower than found for another Danish JEM (26). They constructed the JEM by a combination of expert ratings and objectively measured mechanical shoulder exposures and found that expert-rated job exposures explained between 41–64% of the variance of the measured job exposures (26). This discrepancy may be due to the difference in using self-reported and expert rating when constructing the JEM, in addition to differences in the exposures being evaluated. Compared with individual-based exposure estimates, the predictive validity of our mechanical JEM showed consistently lower, but reproducible associations with low-back pain for both genders. This is consistent with findings from the comparable JEM from Finland (22), which similarly supports the use of this exposure assessment method for evaluating mechanical workload as a risk factor for low-back pain in large-scale registry studies, where more precise exposure measures are not feasible.

For psychosocial work factors, the constructed JEM showed fair-to-poor agreement, with highest ability to identify occupations with exposure to job strain, monotonous work, decision latitude and psychological demands, and lowest for supportive leadership. This largely coincides with comparable JEMs from France, showing fair agreement for psychological demands and decision latitude (20), Australia, for job control and job demands (27) and from Finland, for low control and high strain (23). The findings from previous studies (20, 23, 27), together with our results, equally indicate that low social support and supportive leadership at work are not reliable as group-based estimates or proxies for individual data. It is reasonable to think that supportive leadership is affected more by the type and structure of the company or department, culture, leader and the individual, than occupation itself. The predictive validity of the constructed psychosocial JEM showed an ability to reproduce a significant association between low decision latitude and low-back pain, however, with a loss of significant association between job strain and low-back pain in both genders. The JEM also resulted in a loss of significant association between high monotonous work and low-back pain among women, while among men this association remained significant. In sum, our findings, together with similar studies, support that group-based psychosocial exposures are conservative proxies for individual data as risk factors for low back pain, however, with exception of exposure to supportive leadership/social support at work.

All JEM are crude exposure measures since they are based on group-level exposures and will therefore always represent a loss of individual information. It is evident that some work exposures/factors perform better than

others as aggregated estimates, and we found that our JEM performed better for mechanical than, psychosocial work exposures. In a Dutch study, a JEM included both mechanical and psychosocial workload and showed, similarly as us, that the group-based estimates classified jobs according to mechanical workload more accurately than psychosocial workload (24). This may suggest that, to a lesser degree than mechanical factors, some psychosocial factors are related to specific occupations and that the variation in some psychosocial exposures are only to a limited extent explained by the occupation.

Methodological considerations

The current matrix is based on a randomly drawn large nationwide sample of all Norwegian residents, providing representative data on exposure and outcome for a majority of occupations. Earlier studies recommend 10 subjects in each group to achieve a reliable estimation of exposure (33), however, in the constructed JEM we used a minimum of 19 in each occupational group to increase the reliability of the estimates. The large sample also allowed us to construct a gender-specific JEM. We found that the performance of the constructed JEM differed somewhat between genders. The explained variance estimates for mechanical work exposures was higher among men than women, indicating that, within occupational groups, the exposures to mechanical workload are more similar among men. On the other hand, the explained variance in the psychosocial work exposures was higher among women than men, suggesting that the exposures to psychosocial stressors within occupational groups could be more similar among women. These results further indicate that gender-specific group-based exposure levels are of importance to increase accuracy in the exposure estimates.

Our modeling strategy, using average exposures to calculate gender-specific JEM values, was chosen based on the available self-reported data. Other modeling strategies such as a mixed-effects model (38), enabling a more specific modeling of exposure are often used on data with more detailed exposure assessment (such as objectively technical measurements). These models were not suitable for our exposure data and may limit the use of our JEM in studies where detailed exposure estimates are needed.

The potential for non-differential misclassification of exposures has often been a recurring criticism regarding the validity of job exposure matrices (39). Dichotomous exposures, with the same probability of being misclassified for all study subjects, are assumed to underestimate or attenuate the hypothesized association studied. A study has stated that, in some settings, the use of group-based exposure strategies can result in less biased estimates, eg, if the between-group variance is large (40). In our analysis, we found large between-group variance for exposure to standing/walking and arms elevated, while low between-group variance for supportive leadership and job strain, reflecting a possible bias in these psychosocial exposures. Our results, however, suggest that the magnitude of the misclassification did not impair the JEM's ability to detect the true associations for work exposures, for most exposures.

In the present study, we had access to self-reported mechanical and psychosocial work exposure data from a large nationwide study that covers a large proportion of the STYRK-98 occupational titles. Self-reported exposure data entail methodological challenges, such as differential misclassification leading to recall bias. Furthermore, dependent misclassification and common method bias could be an issue in a study were also the dependent variable, eg, low-back pain, was based on self-report (41). Thus, our use of the same self-reported exposure assessment in both the JEM and the "gold standard" may have positively biased the JEM's performance indicators and we may have overestimates the JEM's ability to detect true associations. However, self-reported exposure could be considered more reliable when using dichotomous exposures (42), as we have done. The cut-off points in exposure levels in the constructed JEM are crucial in optimizing the JEM performance. The use of 50% as cut-off point is common practice, but lower cut-off points for less prevalent exposures have been recommended in recent studies (22). We also based our exposure cut-off levels on several criteria (kappa, sensitivity, specificity and AUC) to optimize the JEM for different occupational exposure estimates. Finally, we evaluated the predictive validity of low-back pain and found it acceptable.

Concluding remarks

It is crucial to be aware that all JEM only provide crude exposure estimates and will never replace the importance of individual exposure measurements in establishing dose−response relationships to guide safe work. It can, however, be a valuable tool in characterizing exposure of workers in epidemiological studies lacking information on work environment. Taking into account the methodological limitations of this study, the constructed matrix for mechanical and psychosocial work exposures showed moderate agreement for most mechanical work exposures and fair agreement for most psychosocial exposures, with exception of supportive leadership, which showed poor agreement. All the JEM estimates for mechanical exposure and psychosocial stressors, such as psychological demands, monotonous work and decision latitude, may be useful in large epidemiological register studies.

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