Report Information from ProQuest

17 October 2023 02:22

TABLE OF CONTENTS

Predicting residential radon concentrations in Finland: Model development, validation, and application to childhood leukemia

Nikkilä, A [1] ; Arvela, H; Mehtonen, J; Raitanen, J; Heinäniemi, M; Lohi, O; Auvinen, A [1] Affiliation: Faculty of Medicine and Health Technology, Tampere University Arvo Ylpön katu 34, 33520 Tampere, Finland. atte.nikkila@tuni.fi

ABSTRACT (ENGLISH)

Objectives Inhaled radon gas is a known alpha-emitting carcinogen linked especially to lung cancer. Studies on higher concentrations of indoor radon and childhood leukemia have conflicting but largely negative results. In this study, we aimed to create a sophisticated statistical model to predict indoor radon concentrations and apply it to a Finnish childhood leukemia case-control dataset.

Methods Prediction was based on ~80 000 indoor radon measurements, which were linked to national registries for potential indoor radon predictors based on the literature. In modelling, we used classical methods, random forests and deep neural networks. We had 1093 cases and 3279 controls from a nationwide case-control study. We estimated odds ratio (OR) for childhood leukemia using conditional logistic regression adjusted for potential confounders.

Results The r2 of the final log-linear model was 0.21 for houses and 0.20 for apartments. Using random forest method, we were able to obtain slightly better fit for both houses (r2 = 0.28) and apartments (r2 = 0.23). In a risk analysis based on the case-control data with log-linear model, we observed a non-significant (P=0.54) increase with predicted radon concentrations [OR for the 2nd quartile 1.08, 95% confidence interval (CI) 0.77-1.50, OR 1.10 with 95% CI 0.79-1.53 for the 3rd, and 1.29 with 95% CI 0.93-1.77 for the highest quartile].

Conclusions Our modelling and the previously published models performed similarly but involves major uncertainties, and the results should be interpreted with caution. We observed a slight non-significant increase in risk of childhood leukemia related to higher average indoor radon concentrations.

FULL TEXT

Headnote

Objectives Inhaled radon gas is a known alpha-emitting carcinogen linked especially to lung cancer. Studies on higher concentrations of indoor radon and childhood leukemia have conflicting but largely negative results. In this study, we aimed to create a sophisticated statistical model to predict indoor radon concentrations and apply it to a Finnish childhood leukemia case-control dataset.

Methods Prediction was based on ~80 000 indoor radon measurements, which were linked to national registries for potential indoor radon predictors based on the literature. In modelling, we used classical methods, random forests and deep neural networks. We had 1093 cases and 3279 controls from a nationwide case-control study. We estimated odds ratio (OR) for childhood leukemia using conditional logistic regression adjusted for potential confounders.

Results The r2 of the final log-linear model was 0.21 for houses and 0.20 for apartments. Using random forest method, we were able to obtain slightly better fit for both houses (r2 = 0.28) and apartments (r2 = 0.23). In a risk analysis based on the case-control data with log-linear model, we observed a non-significant (P=0.54) increase with

predicted radon concentrations [OR for the 2nd quartile 1.08, 95% confidence interval (CI) 0.77-1.50, OR 1.10 with 95% CI 0.79-1.53 for the 3rd, and 1.29 with 95% CI 0.93-1.77 for the highest quartile].
Conclusions Our modelling and the previously published models performed similarly but involves major uncertainties, and the results should be interpreted with caution. We observed a slight non-significant increase in risk of childhood leukemia related to higher average indoor radon concentrations.
Key terms cancer; carcinogen; epidemiology; etiology; indoor radon.
Radon (Rn-222) is an alpha-radioactive element in the decay chain of uranium. It is generated in the ground from the decay of radium and, as a gas, it occurs in high concentration in soil pore air. A number of physical factors and processes are involved in the generation and transfer of radon from mineral grains to soil gas and in the movements of radon-bearing soil air. The entry of soil gas into built spaces is controlled by the flow dynamics of soil air in the porous soil media and through a large variety of gaps, air-permeable building elements and openings in the structures in contact with soil or in floor structures in crawl space houses. Indoor radon concentrations vary widely depending on the uranium concentration of the terrain, soil permeability, entry from the ground to buildings and ventilation (1-3). Finland has one of the highest average residential radon-222 concentrations in the world, 96 Bq/m3, resulting in a mean annual effective dose of 1.6 mSv based on ICRP-65 from 1993 and a dose of 4.5 mSv based on the ICRP-137 (4-6). The new ICRP-137 from 2017 is based on both dosimetric estimates and epidemiology. The radiation dose is largely due to the short-lived progeny rather than radon itself. Dose to the bone marrow from inhaled radon progeny is substantially lower than that to the lung (7, 8).

Health effects of indoor radon

Uranium and hard-rock miners are exposed to very high concentrations of radon progeny and such occupational exposure has been shown to increase the risk of lung cancer (9). Lower residential radon concentrations have also been shown to increase the risk of lung cancer (10). The International Agency for Research on Cancer (IARC, World Health Organization) has classified radon as a recognized Group 1 human carcinogen (11). No excess of leukemia has been consistently associated with radon exposure in uranium miners (12-22).

Results from previous studies on the possible effect of exposure of indoor radon on risk of childhood leukemia have been largely negative but still inconclusive. The potential dose pathway for the association, in addition to the exposure of the red bone marrow, has been suggested to be through the exposure of lymphocytes within the tracheobronchial epithelium (23). Studies in Norway, France, the UK, and Switzerland showed no association, but a Danish case-control study with complete residential histories and a statistical model with 40% r2 reported an elevated risk (24-28). In these studies, exposure estimates were derived from model-based predictions of radon exposure (29-31). Efforts to construct a good prediction models have been made in the UK and detailed information on soil has been essential (32, 33). Some smaller studies have used actual radon measurements but shown no materially elevated risks (34-37). In addition, several ecological studies have evaluated the association between incidence rates and regional average radon levels and have consistently reported positive risk estimates (38).

Estimation of indoor radon

When estimating the effects of indoor radon, or most other environmental exposures, a direct measurement would be the optimal way to define exposure. However, that is not always possible due to practical reasons. To study risk factors of small expected effect size with sufficient statistical power, a large number of subjects is needed, and performing thousands or even millions of repeated on-site radon measurements does not currently appear feasible. Further, participation bias in measurement program is likely to be a significant problem. However, robust results have been reported using statistical models for predicting radon concentrations in similar scenarios (29-31). Many country-specific models have been published with varying performance (29, 39).

Low-rise residential buildings (single family houses, semi-detached houses and terraced houses) will be referred to as houses. Dwellings in multi-story block houses are called apartments.

Indoor radon concentrations are determined by a variety of factors in a complex chain of processes. In low-rise residential houses, the soil-borne radon gas dominates, with regard to indoor radon concentration. The main processes include concentration of uranium in mineral grain, emanation of radon from mineral grains to soil gas, movements of radon-bearing soil air in the porous soil media, and entry of radon-bearing soil gas into living spaces. In foundation structures, gaps, airpermeable building blocks, and openings in the structures increase the soil air entry into indoor spaces. The entry rate is controlled by the flow dynamics of soil air in the porous soil media and physical modelling shows that the air permeability of the sub-soil is a much more important factor than the effective area of the air leakage routes (40). Therefore, the highest values are measured in houses situated in hilly areas with porous soil of coarse gravel, for example on eskers (a long ridge of gravel or other sediment, typically having a winding course, deposited by meltwater from a retreating glacier or ice sheet). The lowest values in low-rise buildings are found in areas of impermeable clay. Air exchange in the building is the process of diluting radon concentration in indoor air (41).

In Finland, in apartment buildings soil-borne radon is not an important radon source, except for apartments on the lowest level and with floors in contact with soil. On upper floors, radon gas emanated from rock-based building materials, normally concrete elements, dominates. The national average indoor radon concentration caused by building materials in apartments is clearly lower (49 Bq/m3) than the average concentrations caused by soil-borne radon in low-rise residential houses (121 Bq/m3) (6). Also, the range of radon concentrations in apartments is narrower compared with houses as the percentage of measurements above 400 Bq/m3 in apartments was 0.7% in the national survey and 3.8% in houses. Uranium concentration of local gravel material can be utilized as a determinant for radon concentration in apartments because gravel has been used as concrete ballast material. Other important predictors of indoor radon are the dwellings age and the existence of cellars in detached houses (42, 43). Also, the story of the dwelling in blocks of flats has been shown to predict the concentration (44, 45). Seasonal variation has also been documented (43). Radon concentrations are highest during the heating season. Indoor radon measurements have been carried out in the period of November-April in Finland (46).

Modelling indoor radon concentrations has been proven to be particularly difficult as limited or no data are available on several important determinants. For example, the type of building foundation correlates strongly with radon concentrations but is rarely available (3, 43). The same stands true also for the type or source of gravel used for the foundation. However, due to the importance of the data from the original building soil, the effect of the lack in the knowledge of the transported layers of mineral material is decreased. Ventilation strategies, either natural or mechanical, are not included in the database of the Population Register Centre of Finland. However, history of the prevalence of ventilation strategies in Finnish low-rise residential buildings is well known based on national sample surveys (6, 41, 47). With regard to modelling, the effect of ventilation strategies seems to be limited compared with uranium concentration in soil or soil permeability (41).

The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003-2004. Thereafter, preventive measures have become more common and effective and, in houses completed since 2006, indoor radon concentrations have been markedly reduced. These data are of great importance when constructing a statistical model. The national radon prevention study in 2009 showed that in houses with preventive measures, the radon concentration was on average reduced by >50% compared with houses with no preventive measures (47).

Furthermore, results from more than 200 000 individual radon measurements in Finnish dwellings are recorded in the database of the Radiation and Nuclear Safety Authority. In Finland, only regional indoor radon modelling has been conducted and no nationwide studies on modelling radon concentrations have been published.

Aims of the study

Using statistics, we modelled indoor radon concentration in a given dwelling using measurements from the nationwide database and internally validated its performance and robustness. Then we applied the model to examine potential association between residential radon and childhood leukemia using data from a nationwide childhood leukemia case-control study (48).

Methods

Radon measurements

We obtained results of all indoor radon measurements (N=244 059) from the database compiled by STUK - the

Radiation and Nuclear Safety Authority and linked them to the building database of the Population Register Center by address and postal code. We used the oldest available measurement from each dwelling to minimize the effect of potential radon protection renovations. If there were two or more measurements with the same start dates, the one with higher measured concentration was used to maximize the models' ability to recognize the high concentrations.

Combining databases

The Population Register Centers building database contains data on a dwelling type (house versus apartment), year of completion, floor area (m2), total area (m2), total volume (m3), number of floors, area of the basement, main building material (rock-based materials, wood, others) and air-conditioning. All predictive variables were required to be available from nationwide registries (Population Registry Center) and, thus, not all important predictors, that were available only in STUK's radon database (type of foundation, radon protection, the floor of the dwelling), could be utilized in modelling.

The linkage of the measurements to the building database of the Population Register Center was based on street address and postal code as the key. This resulted in one-to-many linking problem due to multiple buildings in the same postal address. In such cases, we selected buildings with the best match in terms of building type, year of completion and coordinates.

To deal with the remaining discrepancies between databases (STUK's and the Population Registry Center's Building databases) after the primary selection, we created three sets of filtering criteria to acquire the best compromise between accuracy and sample size. We also aimed to explore whether there would be substantial differences in models with differently filtered radon datasets. The sample sizes of different filtering levels are represented in the figure 1. The first level required >100 m difference in Euclidean distance by coordinates, a >10-year difference in year of completion and no observable discrepancy in building type between the two databases. The second level required that there be no missing values in any of the filtering variables of the first level and thus all filters could be applied to every building (as the first level inhibited missing values from triggering the filter). The third level also allowed for no missing values and involved stricter criteria for >10 m Euclidean distance and identical year of completion. The numbers of buildings fulfilling the three sets of criteria are shown in the figure 1 (with other exclusions).

Radon concentrations in houses and apartments were modelled separately as the major predictors differed based on the literature. Dwellings with missing or ambiguous building type were excluded. For the house model, the median postal-code-specific indoor radon concentration was derived from the 20% of the measure - ments sampled from the dataset left outside modelling to avoid using derivatives of the measurements as predictors. As the average number of dwellings per postal code area was relatively low and the total number of postal areas was relatively high, this resulted in some missing values (N=5697, 3.6%) and, also, some postal areas were represented by only few measurements. For the apartment model, we constructed a database of county-specific median radon concentrations in apartments based on two nationwide representative surveys (conducted in 1991 and 2006) (6, 49). The measurements from the 1991 survey were calibrated to match the values from the more recent survey.

Additional data for the models

To complement the model, we obtained data on the soil type as vector maps and terrain elevation as a 100 x 100 m square map from Geological Survey of Finland (GTK). Regarding the soil type, for each area, the map with the highest resolution (1:20 000, 1:50 000 and 1:100 000) available was used. STUK also provided us with an 8 x 8 km square map of soil uranium concentration (Bq/kg) (50). The vector maps for dwellings were evaluated using QGIS (v. 3.2.1) and square maps were evaluated with a basic R script.

Detailed soil types were classified into three categories by permeability. The classification was based on the grain size distribution of the soil type. Air permeability of soil types is closely related to grain size distribution. Soil air permeability is highest for coarse gravel (grain size 6-20 mm) and lowest for clay with a very low grain size (>0.002 mm). The database presents the soil type at the depth of 1 meter, which is representative of the depth of house foundations. Several terms were created to characterize year of construction: a categorical variable in 5-year intervals, as well as a separate indicator term for pre-1940 were used. For apartments, the latter term was defined with 1950 as the cut-off. The building material was classified as rock-based, wood, or other/ unknown. We also created a binary variable to estimate exhaust fan-based ventilation: any type of ventilation based on the building registry and building completed before year 2000 for houses and any type of ventilation with building completed between 1950 and 2006 for apartments. The presence of a basement was modelled as a three-step variable (no basement, basement and dwelling built before 1990, basement and dwelling built after 1990) due to new prevalent practice of hill-side houses instead of full basement houses.

Model ling i ndoor radon

We applied multiple approaches for developing the two final radon prediction models. The methods were used similarly for both models from predictor selection to vali dation. First, we started with a log-linear model with all ohe available predictors. All continuous potential predictors were log-transformed. We used a backward selection algorithm starting with the full model and used multiple imputation to deal with the missing data. The proportions of missing data for each potential predictor are presented in the supplementary material (www. sjweh.fi/show_abstract.php?abstract_id=3867), table S1. We defined measured indoor radon outliers as values with z>3 and excluded them.

We then created two categorical models with radon concentrations divided into quartiles: a polynomial and a multinomial. We also tested a model with a binary dependent variable by dividing the radon concentration by its 80th percentile. Finally, we experimented with modern machine learning algorithms (random forest and deep neural networks) as an alternative to the traditional methods (51, 52). For random forest models, we set the number of trees grown to 2000 and 560 for apartments and houses, respectively, based on the point, where the model errors started to converge. Deep neural network was specified as a 4-layer network with 256, 128, 64, and 1 nodes with rectified linear unit as activation func- tion in each except the output layer. The model was trained with 80% of the data with additional 20% used as validation for each epoch for 1000 epochs or until convergence according to mean squared error.

We used five-fold cross validation to explore the robustness and potential over-fitting of the log-linear model. We also calculated the Spearman correlation between the measured and predicted indoor radon concentrations. Categorical models were evaluated with Cohen's kappa. We performed sensitivity analyses on different levels of filtering regarding the slight discrepancies between databases.

Childhood leukemia case-control study

The indoor radon exposure was predicted with log-linear model for the cases and controls using our nationwide case-control dataset (48). Briefly, the cases included all Finnish children diagnosed with childhood leukemia during 1990-2011. The 1100 cases were identified from Finnish Cancer Registry (M9800 - M9948 in ICD-O-3). Three controls were individually matched on sex and year of birth to each case from the Finnish Population Register Center. Each control was assigned a reference date to match the diagnosis of the respective case. We assumed a two-year latency based on results summarized by UNSCEAR, which automatically results in null exposure for subjects less than two years of age at their reference date as well as their controls (53). These cases and their respective controls were excluded from the analyses. We obtained also complete residential histories which yielded, in total, 7334 residencies with the aforementioned latency period. As a sensitivity analysis, we experimented with a five-year latency period.

The cases were classified by leukemia subtype into pre-B-ALL (precursor B-cell acute lymphoblastic leukemia), T-ALL (T-cell acute lympoblastic leukemia), unspecified ALL, AML (acute myeloid leukemia) and others. The genetic subtypes were obtained from the hospital records. We obtained data on gestational age, birth weight, maternal smoking from the Medical Birth Registry. Diagnoses of Down syndrome and other congenital malformations were obtained from the Congenital Malformation Registry. In addition, we obtained data on parental education, occupation, and socioeconomic status from Statistics Finland.

When applying the model to the childhood leukemia dataset for subjects (3.0% for cases and 2.6% for controls) with only municipality of residence available (for at least one residence), we used municipalityspecific radon estimates. For residential periods abroad (1.4% for cases and 0.7% for controls), we used worldwide indoor radon average 39

Bq/m3 (54). In the rare cases where a dwelling could not be classified as either a house or an apartment, we also used the municipalityspecific median (1.2% for cases and 1.2% for controls). Otherwise, we applied the model after using multiple imputation for missing data on variables required for the prediction. As the dependent variable of the model was log-transformed before fitting the curve, the predictions represent geometric means of the estimated indoor radon concentrations when transformed back into Bq/m3.

Radon exposure prediction

We calculated cumulative radon exposure as Bq/m3 integrating over time to cover the whole residential history taking two-year latency period into account and divided it into quartiles for the conditional logistic regression analyses. We also calculated the average concentration of the exposure period by dividing the cumulative exposure with the total length of the exposure period. Cumulative exposure accumulates with age and, thus, is highly correlated with it. The analyses were adjusted for potential confounders: Down syndrome (yes or no), large birth weight (LGA) (exceeds 90th birth weight percentile in relation to gestational duration), terrestrial gamma radiation and Chernobyl fallout [cumulative red bone marrow equivalent dose (mSv)], cumulative red bone marrow dose from CT exposure (mGy), maternal smoking during pregnancy (yes or no), as well as parental socioeconomic status and education. Both socioeconomic status and education were known individually for each parent. Socioeconomic status was classified into five classes (self-employed, upper level employee, lower level employee, manual worker and other) and education into three levels (upper secondary, bachelor's degree, master's or doctor's degree) (55).

Statistical analysis

All analyses were performed using R software version 3.4.0. For the modelling and visualization, the R libraries included: multiple imputation (Amelia, v. 1.7.5), k-fold cross validation (DAAG, v. 1.22), Cohen's kappa (psych, v. 1.8.4), Bland-Altman plot (BlandAltmanLeh, v. 0.3.1; ggExtra, v. 0.8; ggplot2, v. 3.1.0), ordered logistic regression (MASS, v. 7.3-51), Brant's test (brant, v. 0.2-0) multinomial logistic regression (nnet, v. 7.3-12), random forests (randomForest, v. 4.6-14), keras (keras, v. 2.2.0). The risk analyses after prediction were carried out with conditional logistic regression from the library survival (v. 2.43-1). Variance inflation was examined using car-library (v. 3.0-2). We used 5% as the significance threshold and all reported p-values are two-sided. For multiple testing corrections we used the BenjaminiHochberg method. Effect modification was investigated by including interaction terms into the model and evaluating improvement in model fit.

Ethical considerations

No informed consent from the study subjects was needed according to the Finnish regulations as the study was carried out entirely through registers and databases, without any contact with the study subjects.

Results

Radon measurements

The median indoor radon concentration in 93 219 unique linked dwellings from the STUK database was 137.3 Bq/m3 (IQR 68.0 Bq/m3, 267.4 Bq/m3), with the 95th percentile 732.7 Bq/m3, the 99th percentile 1913.0 Bq/m3 and the maximum 38,883 Bq/m3. The distribution was log-normal and after log-transformation, the distribution was normalized when evaluated using a Q-Q plot.

After exclusions, the material included 73 903 (94.1%) houses and 3709 (4.7%) apartments, with median radon concentrations 143 Bq/m3 (IQR 71 Bq/m3, 276 Bq/m3) and 66 Bq/m3 (IQR 38 Bq/m3, 134 Bq/m3), respectively. The descriptive statistics and distributions of predictors are represented in tables 1a and b by indoor radon quartiles.

Modelling indoor radon concentrations

The final predictors, their estimates and confidence intervals (CI) with adjusted P-values for the log-linear model are reported in tables 2a, b and c. For the house model, most of the selected predictors had a highly statistically significant effect due to large sample size. Especially for the houses, the construction year displayed an inverted U-shaped curve relationship with indoor radon, with lower concentrations in newer buildings due to stricter radon protection regulation. Rockbased building materials were associated with higher residential radon than wood as a building material, and higher indoor radon concentrations were also associated with more porous soil. Uranium concentration in soil exerted a major influence in the house model. In general, we identified fewer predictors with mostly smaller coefficients for apartments.

For both models (houses and apartments), the year of completion was an important predictor. It explained 10.6% and 4.61% of the variance and for the house and apartments, respectively. Soil permeability was also influential (houses 2.97% and apartments 7.05%). The other proportions of the variation explained by each predictor are reported in table 3. For the final log-linear house model, we observed Akaike's information criterion (AIC) 157 739 and Bayesian information criterion (BIC) 158 036 and for the apartment model AIC 9993 and BIC 10 161.

Performance of the models

The final model of the log-transformed indoor radon concentration reached r2 of 0.21 for the house model and 0.20 the apartment model. The Spearman correlation between the measured and predicted values in the validation dataset was 0.45 for the houses and 0.44 for the apartments. The scatterplots of measured and predicted indoor radon concentrations also showed only a modest correlation with a narrower range of predicted than observed concentrations (figure 2), but both models were unable to accurately identify the lowest and highest radon concentrations (figure 3). In the five-fold crossvalidation with 80-20 split, the models appeared robust with no indication of substantial over-fitting for either model. The mean squared error was 0.84 for the houses and 0.88 for the apartments. We observed variance inflation due to multicollinearity of the predictors. For the apartments, the predictors with generalized varianceinflation (GVIF) >2 were soil permeability (5.1), formation by ice-age (4.3), year of completion (2.3) and soil uranium concentration (2.3). For the house model, five predictors showed GVIF >2: soil permeability (2.6), formation by ice-age (2.4), year of completion (2.6), floor area (2.3) and total volume (2.2).

The weighted Cohen's kappa for measured and predicted values by quartiles of measured indoor radon was 0.33 for houses and 0.38 for apartments. If only one split at 80th percentile was used, the weighted kappa was 0.10 for houses and 0.25 for apartments.

Exploratory modelling attempts

In exploratory analyses, the predictors of both dwelling types remained largely similar when an ordered logistic regression was used instead of the log-linear model to predict indoor radon in quartiles, but the assumption of parallel lines was not met for the categorized year of completion when evaluated with Brant's test. This also applied to multinomial logistic regression. Ordinary logistic regression for binary radon split at p80 gave poor results.

We did not observe major changes in r2 (0.21-0.24 for houses and 0.20-0.24 for apartments) or in the coefficients when different levels of measurement filtering were used. Using modern machine learning methods, we were able to markedly improve the coefficient of determination [random forest (apartments 0.23, houses 0.28), deep neural network (apartments 0.19, houses 0.18)]. We also observed lower coefficients of determination when using the newest available radon concentration for each dwelling.

Childhood leukemia case-control data

After exclusions, we included 1093 (4 had prohibition of data use and 3 had incorrect identification codes) childhood leukemia cases diagnosed in 1990-2011. Of these, 826 (75.6%) were pre-B-ALL, 64 (5.9%) were T-ALL, 20 were unclassified ALL (1.8%), 146 were AML (13.6%), and 34 were other (3.1%). A majority of the cases were diagnosed at age 2-7 years, and the median age was 4.52 [interquartile range (IQR) 2.72, 8.23]. Down syndrome, intrauterine growth, and maternal smoking during pregnancy were associated with risk of childhood leukemia (table S2).

In total, there were 7443 different dwellings (1839 for cases and 5604 for controls) in the subjects' residential histories using the two-year latency period. The residential radon concentrations were estimated with either the house (56.1%, N=1032 for cases and 54.9%, N=3079 for controls) or the apartment model (38.3%, N=704 for cases and 40.5%, N=2271 for controls), except for 5.6% for cases and 4.5% for controls for whom municipality-specific medians were imputed due to lack of dwelling data.

Evaluating the model against direct measurements

Direct measurements were available for 1.4% (N=103) of the subjects' residential periods (1.4%, N=25 for cases and 1.4%, N=78 for controls) when linking by address, city and the time period of the measurement to STUK radon database. The Spearman correlation between the predicted and measured radon concentrations of the subjects was 0.36 and r2 was 0.10 after log-transformation. If direct measurements were matched also by year of completion (maximum 1-year discrepancy) and by coordinates (maximum 100 m Euclidean distance), there were, in total, 55 measurements [14 (25%) for cases, and 41 (75%) for controls], and the Spearman correlation rose to 0.45 and the r2 became 0.11.

Predicted radon concentrations

We made predictions of indoor radon concentration for each residential period with both the log-linear and random forest models. The correlation between these predictions for apartments was 0.52 and 0.49 for houses. Respectively, the correlation between the cumulative exposures (Bq/m3 years) of subjects was higher (0.93) and for the average concentration it was only 0.29, reflecting the effect of the total duration of all residential periods of each subject.

Using the log-linear model, the median predicted cumulative indoor radon exposure was 301 Bq/m3 years (IQR 121 Bq/m3 years, 625 Bq/m3 years) for the cases and 292 Bq/m3 years (IQR 116 Bq/m3 years, 636 Bq/m3 years) for the controls. The median of the time-weighted average indoor radon concentration was 92 Bq/m3 (IQR 68 Bq/m3, 123 Bq/m3) for cases and 89 Bq/m3 (IQR 67 Bq/m3, 121 Bq/m3) for controls. For the random forests model, the median cumulative exposure among the cases was 357 Bq/m3 years (IQR 151 Bq/m3 years, 789 Bq/ m3 years) and for the controls 357 Bq/m3 years (IQR 152 Bq/m3 years, 799 Bq/m3 years). The median of the average concentration for cases was 107 Bq/m3 (IQR 93 Bq/m3, 127 Bq/m3) and for controls 107 Bq/m3 (IQR 93 Bq/m3, 128 Bq/m3).

Risk analyses

In unadjusted analysis of exposure predicted with the log-linear models, we observed an odds ratio (OR) of 0.87 (95% CI 0.63-1.19) for an increase of 1000 Bq/m3 years in cumulative radon exposure. When the model was adjusted for potential confounders the OR was 1.06 (95% CI 0.59-1.92). The results from both unadjusted and adjusted models for cumulative exposure, average concentration and quartiles are presented in table 4 based on log-linear and random forest predictions. The dose-response curves based on quartiles are presented in figure 4 for predictions from both modelling approaches.

Exploratory and sensitivity analyses

In exploratory subgroup analyses for ALL patients with the log-linear model, we found an adjusted OR of 1.32 (95% CI 0.67-2.60) for every 1000 Bq/m3-years. Similarly, for subjects diagnosed before turning 6 years, the OR was 3.53 (95% CI 0.80-15.5). All subgroup analyses for both cumulative exposure and average concentration with log-linear and random forest predictions are shown in the supplementary table S3. The interaction term was not significant for subtypes nor age-groups.

As sensitivity analysis, we explored the effect of a longer, 5-year, latency period (489 cases and 1467 controls). In unadjusted analyses with log-linear model, we observed an OR of 0.70 (95% CI 0.42-1.18) for an increase of 1000 Bq/m3 in cumulative exposure and when adjusted the similar OR was 0.93 (95% CI 0.33-2.63). The analysis of quartiles of average concentration showed no evidence of elevated risk and the central estimates of all but the reference quartile were below unity (data not shown).

Discussion

Main findings

We constructed two prediction models to estimate indoor radon concentrations in Finland using both technical properties of the buildings and geological properties of the terrain under the building. Our models performed reasonably well compared to previous modelling attempts, showed no imminent signs of overfitting and behaved robustly in multiple sensitivity analyses. However, the prediction model was unable to distinguish radon concentration deviating strongly from the average but modelling the highest concentrations (>10 000 Bq/ m3) was never the aim as they are not reachable with traditionally available data. We applied the model to a nationwide register-based case-control dataset of childhood leukemia and observed a slight, non-significant trend risk, with the OR 1.1-1.3 (95% CI 0.79-1.77) for radon concentrations >120 Bq/m3.

The distributions of the predictions produced by our models (92 Bq/m3 for cases, 89 Bq/m3 for controls) were in line with the previously published median Finnish indoor radon concentration (96 Bq/m3) (6, 56). The performance of our main model was similar (r^2 = 0.21) to the recent, similarly constructed model from Switzerland (29). Higher coefficients of determination in some previous country-specific models may be related to smaller numbers of measurements (30, 57, 58). We were also able to reach slightly higher coefficients of determination using the random forest machine learning method. However, the small absolute difference in r^2 (maximum 0.07 units), suggests no dramatic improvement over the simpler, and thus to some degree more preferable, classic approach with the log-linear model.

Strengths of the study

Regardless of the sub-optimal performance, the various strengths of our study, with its sophisticated modern machine-learning methods, make it the most up-to-date statistics-based attempt to study indoor radon and childhood leukemia. Our prediction models were created with a comprehensive roster of predictors. Both building properties and geological variables were used. The predictors were collected from nationwide registries. The sample size of direct indoor radon measurements, on which the model is based, is the largest to date. We used multiple approaches when building the optimal model and also saw potential in modern machine-learning methods, especially in the random forest method.

Limitations of the study

However, our study had also limitations. First, our prediction model failed to identify residences toward the high and low ends of the indoor radon range, as is apparent in the Bland-Altman plots. This shortcoming was not rectified by the machine learning methods. Unlike most countries, Finnish indoor radon concentrations can be >10 000 Bq/m^3, which poses major challenges for the prediction and also means that models created for other European countries cannot be applied to the Finnish predictions. To combat the issue, we used the oldest measurements when there were multiple available to avoid the interference of potential radon protection installations and also used the highest available measurement from each measurement session if concentrations were, for example, measured in multiple rooms. This approach resulted in higher coefficients of determination. In the Swiss study using an approach comparable to our log-linear model, the median predicted radon concentration was 77.7 Bq/m^3 and the 90th percentile was 139.9 Bq/m^3 (29). The respective statistics in our data were 89.9 Bq/m^3 and 154.1 Bq/m^3. In the Danish study, the median of the predicted concentrations was considerably lower (41 Bq/m^3) (26).

Second, even though the used soil type maps were vector-based with resolution sufficient to minimize misclassification, the soil types in maps were defined manually and borders between soil types may involve some inaccuracies.

Third, multicollinearity of the predictors cannot be entirely avoided and this may weaken the distinction between predictor contributions and this was observed as higher variation inflation factors. The year of completion reflects multiple building properties and it was one of the strongest predictors of indoor radon also included in the model. It is, however, a proxy indicator for building techniques that we were unable to capture directly and is therefore a suboptimal predictor. The missing important predictors included the type of foundation and the type of stabilizing soil used directly under the foundation as well as accurate ventilation flow patterns.

Fourth, the county-specific median indoor radon concentrations in the apartment model are based on measurements that are included in the apartment model, introducing an element of circular logic. Excluding the survey measurements would have decreased the apartment sample roughly by half. This issue was avoided with houses by randomly selecting a 20% subsample, which was then left outside modelling. Overall, these issues likely overestimated the predictive capacity of our models.

Finally, when the performance of the model was evaluated with direct measurements, we saw some signs of overfitting as the correlation coefficients and the r^2 values were lower than in other means of estimating model performance. Using more stringent criteria for identifying direct measurements did not completely solve the issue. Also, the predictions made by log-linear and random forest models were not highly similar which also displays another uncertainty in our exposure assessment strategy.

The performance of the prediction model was not optimal despite large and high-quality data available for the predictors. The fact that even rich data combined with sophisticated statistical methods fails to capture variability in indoor radon between dwellings shows that results obtained in some other countries are not applicable in the Finnish context and casts some doubt about their broader generalizability. Differences may also reflect a more complex set of determinants in the Finnish context (and broader range of radon levels). Improved prediction models would likely require new modelling approaches or more complete building characteristics.

Integration of the findings with previous studies

As in the recent Norwegian and Swiss analyses, we did not observe a significantly increased risk of childhood leukemia associated with indoor radon. Hauri et al (26) compared the highest 90th percentile to subjects below median and reported an adjusted HR of 0.95 (95% CI 0.63-1.43). Kollerud et al (31) found an adjusted HR of 0.93 (95% CI 0.76, 1.13) per 100 Bq/m3 increment. Also, the analyses from United-Kingdom and France did not report increased risks related to higher indoor radon concentrations (27, 28). The British study reported an RR of 1.03 (95% CI 0.96-1.11) for every 1 mSv increase in cumulative red bone marrow dose as the French study reported and standardized incidence ratio of 1.01 (95% CI 0.91-1.12) for an increase of 100 Bq/m3 in the indoor radon concentration.

Interestingly, a Danish study by Raaschou-Nielsen et al (24) reported an increased risk for childhood ALL (RR 1.53, 95% CI 1.05-2.30 for a 1000 Bq/m3-year increase in cumulative exposure). The Danish study was based on a radon prediction model with a high r2 (40%). They were also able to utilize complete residential histories and adjust for a number of potential confounders. The CI of the Danish study overlap with the results we observed.

Several small case-control studies have used direct residential radon measurements and failed to show a consistent exposure-effect gradient (34-37). They have been frequently limited, however, by lack of complete residential histories and potential selection bias.

When applying the model to our childhood leukemia case-control dataset, we were able to use complete residential histories. The register-based approach minimized selection bias. We adjusted for multiple potential confounders and used a two-year latency period to focus on etiologically relevant exposure.

However, the conclusions that can be drawn from the risk analyses are dependent on our ability to predict the exposure, and the limitations in the prediction model performance are likely to introduce exposure misclassification. As this is most likely similar for cases and controls, non-differential random error is expected to dilute any true effect and a null result may reflect either real lack of an effect or an effect largely masked by misclassification. Also, the dilemma of optimal research strategy remains in choosing between an analysis with inaccurate exposure assessment in a large and representative sample (as register-based studies with predicted radon) or an analysis with accurate direct measurements in a smaller sample potentially affected by selection bias.

Concluding remarks

Our modelling of indoor radon concentration involves major uncertainties, and the results should be interpreted with caution. However, we observed a slight non-significant risk of childhood leukemia related to higher average indoor radon concentrations and results are suggestive of a higher risk for ALL patients and patients under six years of age. In future studies using predictive models, identifying the dwellings with the high radon concentrations, preferably up to 2000 Bq/m3, should be prioritized and, whenever possible, direct measurements should be chosen over modelling.

Acknowledgements

We thank STUK for the data on indoor radon measurements (RATIKKA) and the Geological Survey of Finland for the open access data on soil composition (Hakku). We thank Olli Holmgren for his insightful comments on the development of the model and usage of the STUK data. Funding for the study was obtained from the Finnish Foundation for Pediatric Research, Väre Foundation for Pediatric Cancer Research, Finnish Cultural Foundation and Competitive State Research Financing of the Expert Responsibility area of Tampere University Hospital (9T030, 9U030, and 9V033).

Ethics approval and consent to participate

The study protocol (tracking number R14074) was reviewed by the ethical committee of Pirkanmaa Hos- pital District and no informed consent was needed in accordance with the Finnish regulations. We also obtained a permission

(tracking no. 1774/5.05.00/2014) from the National Institute of Health and Welfare for record linkages with the Finnish Cancer Registry, Medical Birth Register, Care Register for Health Care, and Congenital Malformation Register. A permission to use the socioeconomic data was obtained from Statistics Finland (TK-52-306-16).
Availability of data and materials
Due to the strict data privacy policies in the European Union and Finland, we are not able to provide the full data used in this study. The data could not be anonymized to the minimum of five unique rows due to the large number of variables compared to the number of observations. Under the current jurisdiction, pseudonymized data cannot be published openly.
Competing interests
The authors declare no conflicts of interests.
Sidebar
Indoor radon prediction models were created based on ~80 000 measurements and modern machine learning methods were used in modelling. The performance of the models was comparable to the previously published ones. We observed a non-significant risk of childhood leukemia from indoor radon. However, the modelling involves some uncertainties.
Key terms: cancer; carcinogen; childhood leukemia; epidemiology; etiology; Finland; Finland; indoor radon; leukemia; radon; radon concentration
This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31763683
Additional material
Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.
Nikkilä A, Arvela H, Mehtonen J, Raitanen J, Heinäniemi M, Auvinen A. Predicting residential radon concentrations in Finland: Model development, validation, and application to childhood leukemia. Scand J Work Environ Health. 2020;46(3):278-292. doi:10.5271/sjweh.3867
Correspondence to: Atte Nikkilä, Faculty of Medicine and Health Technology, Tampere University Arvo Ylpön katu 34, 33520 Tampere, Finland. [E-mail: atte.nikkila@tuni.fi]
Footnote
1 Faculty of Medicine and Health Technology, Tampere University, Tampere, Finland.
2 STUK - Radiation and Nuclear Safety Authority, Helsinki, Finland.
3 Institute of Biomedicine, University of Eastern Finland, Kuopio, Finland.
4 Faculty of Social Sciences, Unit of Health Sciences, Tampere University, Finland.
5 UKK Institute for Health Promotion Research, Tampere, Finland.
6 Tampere Center for Child Health Research, Tampere, Finland.
References
References
1. UNSCEAR. Sources and effects of ionizing radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2000 report to the General Assembly, with scientific annexes. New York: United Nations; 2000.
2. Hofmann W, Arvela HS, Harley NH, Marsh JW, McLaughlin J, Röttger A, et al. ICRU Report 88. J Int Comm Radiat Units Meas. 2012;12(2):169-91. https://doi. org/10.1093/jicru/ndv016.
3. Mäkeläinen I, Arvela H, Voutilainen A. Correlations between radon concentration and indoor gamma dose rate, soil permeability and dwelling substructure and ventilation. Sci Total Environ 2001 May;272(1-3):283-9. https://doi. org/10.1016/S0048-9697(01)00705-7.
4. Protection Against Radon-222 at Home and at Work. ICRP Publication 65. Ann. ICRP 23. ICRP; 1993.
5. Paquet F, Bailey MR, Leggett RW, Lipsztein J, Marsh J, Fell TP et al.; Authors on Behalf of ICRP. ICRP Publication 137: Occupational Intakes of Radionuclides: Part 3. Ann ICRP 2017 Dec;46(3-4): 1-486.
6. Mäkeläinen I, Kinnunen T, Reisbacka H, Valmari T, Arvela H. Radon in Finnish dwellings - Sample Survey 2006

(in Finnish, abstract in English). Helsinki: Radiation and Nuclear Safety Authority; 2009.
7. Kendall GM, Fell TP, Harrison JD. Dose to red bone marrow of infants, children and adults from radiation of natural origin. J Radiol Prot 2009 Jun;29(2):123-38. https://doi. org/10.1088/0952-4746/29/2/001.
8. Kendall GM, Fell TP. Doses to the red bone marrow of young people and adults from radiation of natural origin. J Radiol Prot 2011 Sep;31(3):329-35. https://doi. org/10.1088/0952-4746/31/3/002.
9. Health Effects of Exposure to Radon. BEIR VI. Washington, D.C.: National Academies Press; 1999. https://doi. org/10.17226/5499.
10. Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 2005 Jan;330(7485):223. https:// doi.org/10.1136/bmj.38308.477650.63.
11. World Health Organization. WHO handbook on indoor radon: a public health perspective. Geneva, Switzerland: World Health Organization; 2009.
12. Laurier D, Valenty M, Tirmarche M. Radon exposure and the risk of leukemia: a review of epidemiological studies. Health Phys 2001 Sep;81(3):272-88. https://doi. org/10.1097/00004032-200109000-00009.
13. Morrison HI, Semenciw RM, Mao Y, Wigle DT. Cancer mortality among a group of fluorspar miners exposed to radon progeny. Am J Epidemiol 1988 Dec;128(6):1266-75. https://doi.org/10.1093/oxfordjournals.aje.a115080.
14. Hodgson JT, Jones RD. Mortality of a cohort of tin miners 1941-86. Br J Ind Med 1990 Oct;47(10):665-76.
15. Tirmarche M, Raphalen A, Allin F, Chameaud J, Bredon P. Mortality of a cohort of French uranium miners exposed to relatively low radon concentrations. Br J Cancer 1993 May;67(5):1090-7. https://doi.org/10.1038/bjc.1993.200.
16. Tomásek L, Darby SC, Swerdlow AJ, Placek V, Kunz E. Radon exposure and cancers other than lung cancer among uranium miners in West Bohemia. Lancet 1993 Apr;341(8850):919-23. https://doi.org/10.1016/01406736(93)91212-5.
17. Darby SC, Whitley E, Howe GR, Hutchings SJ, Kusiak RA, Lubin JH et al. Radon and cancers other than lung cancer in underground miners: a collaborative analysis of 11 studies. J Natl Cancer Inst 1995 Mar;87(5):378-84. https://doi. org/10.1093/jnci/87.5.378.
18. Darby SC, Radford EP, Whitley E. Radon exposure and cancers other than lung cancer in Swedish iron miners. Environ Health Perspect 1995 Mar;103 Suppl 2:45-7.
19. Rericha V, Kulich M, Rericha R, Shore DL, Sandler DP. Incidence of leukemia, lymphoma, and multiple myeloma in Czech uranium miners: a case-cohort study. Environ Health Perspect 2006 Jun;114(6):818-22. https://doi.org/10.1289/ ehp.8476.
20. Zablotska LB, Lane RS, Frost SE, Thompson PA. Leukemia, lymphoma and multiple myeloma mortality (1950-1999) and incidence (1969-1999) in the Eldorado uranium workers cohort. Environ Res 2014 Apr;130:43-50. https://doi. org/10.1016/j.envres.2014.01.002.
21. Navaranjan G, Berriault C, Do M, Villeneuve PJ, Demers PA. Cancer incidence and mortality from exposure to radon progeny among Ontario uranium miners. Occup Environ Med 2016 Dec;73(12):838-45. https://doi.org/10.1136/ oemed-2016-103836.
22. Kreuzer M, Sobotzki C, Fenske N, Marsh JW, Schnelzer M. Leukaemia mortality and low-dose ionising radiation in the WISMUT uranium miner cohort (1946-2013). Occup Environ Med 2017 Mar;74(4):252-8. https://doi. org/10.1136/oemed-2016-103795.
23. Harley NH, Robbins ES. Radon and leukemia in the Danish study: another source of dose. Health Phys 2009 Oct;97(4):343-7. https://doi.org/10.1097/ HP.0b013e3181ad8018.
24. Raaschou-Nielsen O, Andersen CE, Andersen HP, Gravesen P, Lind M, Schüz J et al. Domestic radon and childhood cancer in Denmark. Epidemiology 2008 Jul;19(4):536-43. https://doi.org/10.1097/EDE.0b013e318176bfcd.
25. Del Risco Kollerud R, Blaasaas KG, Claussen B. Risk of leukaemia or cancer in the central nervous system among children living in an area with high indoor radon concentrations: results from a cohort study in Norway. Br J

Cancer 2014 Sep;111(7):1413-20. https://doi.org/10.1038/ bjc.2014.400.
26. Hauri D, Spycher B, Huss A, Zimmermann F, Grotzer M, von der Weid N et al.; Swiss National Cohort; Swiss Paediatric Oncology Group (SPOG). Domestic radon exposure and risk of childhood cancer: a prospective census-based cohort study. Environ Health Perspect 2013 Oct;121(10):1239-44. https://doi.org/10.1289/ehp.1306500.
27. Demoury C, Marquant F, Ielsch G, Goujon S, Debayle C, Faure L et al. Residential Exposure to Natural Background Radiation and Risk of Childhood Acute Leukemia in France, 1990-2009. Environ Health Perspect 2017 Apr;125(4):71420. https://doi.org/10.1289/EHP296.
28. Kendall GM, Little MP, Wakeford R, Bunch KJ, Miles JC, Vincent TJ et al. A record-based case-control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980-2006. Leukemia 2013 Jan;27(1):3-9. https:// doi.org/10.1038/leu.2012.151.
29. Hauri DD, Huss A, Zimmermann F, Kuehni CE, Röösli M. A prediction model for assessing residential radon concentration in Switzerland. J Environ Radioact 2012 Oct;112:83-9. https://doi.org/10.1016/jjenvrad.2012.03.014.
30. Andersen CE, Raaschou-Nielsen O, Andersen HP, Lind M, Gravesen P, Thomsen BL et al. Prediction of 222Rn in Danish dwellings using geology and house construction information from central databases. Radiat Prot Dosimetry 2007;123(1):83-94. https://doi.org/10.1093/rpd/ncl082.
31. Kollerud R, Blaasaas K, Ganerød G, Daviknes HK, Aune E, Claussen B. Using geographic information systems for radon exposure assessment in dwellings in the Oslo region, Norway. Nat Hazards Earth Syst Sci 2014;14:739-49. https://doi.org/10.5194/nhess-14-739-2014.
32. Ferreira A, Daraktchieva Z, Beamish D, Kirkwood C, Lister TR, Cave M et al. Indoor radon measurements in south west England explained by topsoil and stream sediment geochemistry, airborne gamma-ray spectroscopy and geology. J Environ Radioact 2018 Jan; 181:152-71. https:// doi.org/10.1016/jjenvrad.2016.05.007.
33. Elío J, Crowley Q, Scanlon R, Hodgson J, Zgaga L. Estimation of residential radon exposure and definition of Radon Priority Areas based on expected lung cancer incidence. Environ Int 2018 May; 114:69-76. https://doi. org/10.1016/j.envint.2018.02.025.
34. Lubin JH, Linet MS, Boice JD Jr, Buckley J, Conrath SM, Hatch EE et al. Case-control study of childhood acute lymphoblastic leukemia and residential radon exposure. J Natl Cancer Inst 1998 Feb;90(4):294-300. https://doi. org/10.1093/jnci/90.4.294.
35. Kaletsch U, Kaatsch P, Meinert R, Schüz J, Czarwinski R, Michaelis J. Childhood cancer and residential radon exposure - results of a population-based case-control study in Lower Saxony (Germany). Radiat Environ Biophys 1999 Sep;38(3):211-5. https://doi.org/10.1007/s004110050158.
36. Steinbuch M, Weinberg CR, Buckley JD, Robison LL, Sandler DP. Indoor residential radon exposure and risk of childhood acute myeloid leukaemia. Br J Cancer 1999 Nov;81(5):900-6. https://doi.org/10.1038/sj.bjc.6690784.
37. UK Childhood Cancer Study Investigators. The United Kingdom Childhood Cancer Study of exposure to domestic sources of ionising radiation: 1: radon gas. Br J Cancer 2002 Jun;86(11):1721-6. https://doi.org/10.1038/sj.bjc.6600276.
38. Tong J, Qin L, Cao Y, Li J, Zhang J, Nie J et al. Environmental radon exposure and childhood leukemia. J Toxicol Environ Health B Crit Rev 2012;15(5):332-47. https://doi.org/10.1080/10937404.2012.689555.
39. Branion-Calles MC, Nelson TA, Henderson SB. A geospatial approach to the prediction of indoor radon vulnerability in British Columbia, Canada. J Expo Sci Environ Epidemiol 2016 Nov;26(6):554-65. https://doi. org/10.1038/jes.2015.20.
40. Revzan KL, Fisk WJ. Modeling Radon Entry into Houses with Basements: The Influence of Structural Factors. Indoor Air 1992;2:40-8. https://doi.org/10.1111/j.16000668.1992.05-21.x.
41. Arvela H, Holmgren O, Reisbacka H, Vinha J. Review of low-energy construction, air tightness, ventilation strategies and indoor radon: results from Finnish houses and apartments. Radiat Prot Dosimetry 2014 Dec;162(3):35163. https://doi.org/10.1093/rpd/nct278.
42. Barros-Dios JM, Ruano-Ravina A, Gastelu-Iturri J, Figueiras A. Factors underlying residential radon concentration: results from Galicia, Spain. Environ Res 2007 Feb;103(2):185-90. https://doi.org/10.1016/j.

envres.2006.04.008.
43. Mäkeläinen I, Valmari T, Reisbacka H, Kinnunen T, Arvela H. Indoor radon and construction practices of Finnish homes from 20th to 21st century (Full paper for oral presentation S0311). Proc Third Eur IRPA Congr 2010 June 14-16 Hels Finl. 2010.
44. Lorenzo-González M, Ruano-Ravina A, Peón J, Piñeiro M, Barros-Dios JM. Residential radon in Galicia: a cross- sectional study in a radon-prone area. J Radiol Prot 2017 Sep;37(3):728-41. https://doi.org/10.1088/1361-6498/ aa7922.
45. Valmari T, Arvela H, Reisbacka H. Radon in Finnish apartment buildings. Radiat Prot Dosimetry 2012 Nov;152(1-3):146-9. https://doi.org/10.1093/rpd/ncs2n.
46. Arvela H, Holmgren O, Hänninen P. Effect of soil moisture on seasonal variation in indoor radon concentration: modelling and measurements in 326 Finnish houses. Radiat Prot Dosimetry 2016 Feb;168(2):277-90. https://doi. org/10.1093/rpd/ncv182.
47. Arvela H, Holmgren O, Reisbacka H. Radon prevention in new construction in Finland: a nationwide sample survey in 2009. Radiat Prot Dosimetry 2012 Mar;148(4):465-74. https://doi.org/10.1093/rpd/ncr192.
48. Nikkilä A, Erme S, Arvela H, Holmgren O, Raitanen J, Lohi O et al. Background radiation and childhood leukemia: A nationwide register-based case-control study. Int J Cancer 2016 Nov;139(9):1975-82. https://doi.org/10.1002/ ijc.30264.
49. Arvela H, Castrén O, Mäkeläinen I. Survey of residential radon in Finland, STUK-A108 (in Finnish). Helsinki: Säteilyturvakeskus; 1993.
50. Arvela H, Markkanen M, Lemmelä H. Mobile Survey of Environmental Gamma Radiation and Fall-Out Levels in Finland After the Chernobyl Accident. Radiat Prot Dosimetry 1990;32:177-84. https://doi.org/10.1093/ oxfordjournals.rpd.a080734.
51. Breiman L. Random Forests. Mach Learn 2001;45:5-32. https://doi.org/10.1023/A:1010933404324.
52. Schmidhuber J. Deep learning in neural networks: an overview. Neural Netw 2015 Jan;61:85-117. https://doi. org/10.1016/j.neunet.2014.09.003.
53. UNSCEAR. Effects of radiation exposure on children. 2013.
54. UNSCEAR. Sources and effects of ionizing radiation. 2008.
55. Nikkilä A, Raitanen J, Lohi O, Auvinen A. Radiation exposure from computerized tomography and risk of childhood leukemia: finnish register-based case-control study of childhood leukemia (FRECCLE). Haematologica 2018 Nov;103(11):1873-80. https://doi.org/10.3324/ haematol.2018.187716.
56. Muikku M, Bly R, Kurttio P, Lahtinen J, Lehtinen M, Siiskonen T et al. Suomalaisten keskimääräinen efektiivinen annos: Annoskakku 2012. [Abstract available in English] Säteilyturvakeskus; 2014.
57. Verger P, Hubert P, Cheron S, Bonnefous S, Bottard S, Brenot J. Use of Field Measurements in Radon Mapping in France. Radiat Prot Dosimetry 1994;56:225-9. https://doi. org/10.1093/rpd/56.1-4.225.
58. Verdi L, Weber A, Stoppa G. Indoor radon concentration forecasting in South Tyrol. Radiat Prot Dosimetry 2004;111(4):435-8. https://doi.org/10.1093/rpd/nch069.
Received for publication: 20 March 2019

DETAILS

Subject:	Leukemia; Epidemiology; Buildings; Control data (computers); Carcinogens; Artificial neural networks; Lung cancer; Residential areas; Soil permeability; Indoor air pollution; Statistical analysis; Risk analysis; Ventilation; Radon; Indoor environments; Children; Confidence intervals; Apartments; Prevention; Health risk assessment; Air leakage; Regression analysis; Bone marrow; Control methods; Statistical models; Mathematical models; Neural networks

Location:	United Kingdom--UK; Finland
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	278-292,278A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3867
ProQuest document ID:	2406987392
Document URL:	https://www.proquest.com/scholarly-journals/predicting-residential-radon-concentrations/docview/2406987392/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2022-05-06
Database:	Public Health Database

Document 2 of 12

The impact of office design on medically certified sickness absence

Nielsen, M B; Knardahl, S

ABSTRACT (ENGLISH)

Objective The aim of this study was to determine the impact of three different office designs (cellular office, shared office, and open-plan workspace) on the risk of medically certified sickness absence and the number of days, respectively, of medically certified sickness absence over a 12-month follow-up period. Methods The study relied on a combination of self-report survey questionnaire data on office design supplemented with official registry data number of days with sickness absence from the Norwegian Labor and Welfare Administration. The sample comprised 6328 Norwegian office workers (57% women, age range: 19-70 years, mean age: 44 years). Results Adjusting for survey year, employees working in a shared office [risk ratios (RR) 1.18, 95% confidence interval (CI) 1.10-1.27] and an open-plan workspace (RR 1.12, 95% CI 1.02-1.22) had significantly higher risk of having had medically instances of certified sickness absence when compared to employees working in a cellular-office. Office design was not related to the number of days with absence. The associations were consistent across organizational affiliation, age, gender, whether the respondent had leadership responsibility, and educational level. Conclusion The use of shared offices and open-plan workspaces is a risk factor for medically certified sickness absence. Providing employees with the opportunity to work in cellular offices may reduce absence rates. Key terms cellular office; health; open office; open-plan office; registry data; shared office; shared workstation; sick leave; workability.

FULL TEXT

Headnote

Objective The aim of this study was to determine the impact of three different office designs (cellular office, shared office, and open-plan workspace) on the risk of medically certified sickness absence and the number of days, respectively, of medically certified sickness absence over a 12-month follow-up period.

Methods The study relied on a combination of self-report survey questionnaire data on office design supplemented with official registry data number of days with sickness absence from the Norwegian Labor and Welfare Administration. The sample comprised 6328 Norwegian office workers (57% women, age range: 19-70 years, mean age: 44 years).

Results Adjusting for survey year, employees working in a shared office [risk ratios (RR) 1.18, 95% confidence interval (CI) 1.10-1.27] and an open-plan workspace (RR 1.12, 95% CI 1.02-1.22) had significantly higher risk of having had medically instances of certified sickness absence when compared to employees working in a cellular-office. Office design was not related to the number of days with absence. The associations were consistent across organizational affiliation, age, gender, whether the respondent had leadership responsibility, and educational level.

Conclusion The use of shared offices and open-plan workspaces is a risk factor for medically certified sickness absence. Providing employees with the opportunity to work in cellular offices may reduce absence rates.

Key terms cellular office; health; open office; open-plan office; registry data; shared office; shared workstation; sick leave; workability.

The change from cellular offices to open-plan and shared workspaces is a common trend in contemporary working life (1-3). Previous research has established associations between office design and outcomes such as health, well-being, and self-reported sickness absence (4-6). A prospective study of Swedish employees found a significant excess risk of short- and long-term self-reported sickness absence for employees working in open-plan workspaces (7). Similarly, a study from Denmark found that occupants of a shared office and those working in an open-plan workspace had significantly more days of self-reported sickness absence than occupants of cellular offices (8). Explanations for why open-plan or shared workspaces are risk factors for sickness absence are reduced personal control and privacy, increased noise, higher risk of infections, and different group dynamics when compared to cellular offices (7).

As the majority of previous studies on the health outcomes of office designs have been based on selfreport survey data, often with cross-sectional designs, the potential for causal inferences is limited. There is, therefore, a need for prospective studies that link office designs with objective absence data (7, 9).

Using official registry data on sickness absence, this study determined the impact of three different office designs (cellular office, shared office, and openplan workspace) on the risk and number of days of medically certified sickness absence over a 12-month time period. Following the findings from self-report studies, it was expected that employees in shared offices and open-plan workspaces would have both higher risk medically certified absence and more days of sickness absence compared to employees in cellular offices.

Methods

Study design

This study was a part of the research project "The new workplace II: work factors, sickness absence, and exit from working life among Norwegian employees". The study protocol provides a full description of the research project, procedure, and data material, including demographic information (10). The project was based on a questionnaire survey combined with official registry data on disability benefits. The survey part comprised data from a large sample of adults employed in a full- or parttime position. Subjects were recruited from organizations in Norway that accepted to participate in the study. All employees, excluding those on sick leave, were mailed a letter that explained the aims of the project and assured that responses would be treated confidentially. The survey was web-based, although participants with limited access to computers were given the option of completing a paper version of the questionnaire.

From November 2004 to 15 December 2014, 97 organizations participated in the project. A total of 31 823 employees were invited to participate in the survey. Altogether 15 282 persons responded (response rate 48%), and 14 501 (95%) respondents permitted linking survey questionnaire data to registry data. About 85% of the respondents answered the questionnaire using the electronic survey form, and about 15% used the paper form. After removing respondents that did not work in an office, the final sample for this study comprised 6328 respondents.

The Regional Committees for Medical and Health Research Ethics (REC) in Norway (REC South East) and the Norwegian Data Protection Authority approved this study, which was conducted in accordance with the World Medical Association Declaration of Helsinki. All study participants provided their informed consent. Only respondents who permitted the linking of their answers to sickness absence registries were included.

Registry data and questionnaire instruments

Office design was assessed with a single item question that asked "Do you work...." (i) "alone in your own office"; (ii) "in a shared office with one or more colleagues"; (iii) "in an open-plan workspace"; (iv) "in a shop/service station etc."; (v) "in a treatment institution"; (vi) "outdoors"? Respondents who reported the last three alternatives were not included in this study as they do not work in an office.

The general rules for sickness absence in Norway provide employees with the ability to self-declare sickness absence for <3 continuous calendar days at a time. Sickness absence for >3 calendar days must be certified by authorized medical personnel and are reported to the Norwegian Labour and Welfare Administration (NAV). Self-declared sick leave can be used four times in the course of a 12-month period.

We accessed information on medically certified sickness absence from the Norwegian Labour and Welfare Administration (NAV). The registry provides complete registrations of all medically certified sickness absence. The current study had access to data on total number of days with medically certified absence over a 12-month period, but not on the number of absence spells, duration of spells, or medical diagnosis. Hence, the analyses included whether or not the respondents had >1 instance of medically certified sickness absence and the total number of days over a 12-month period. The registry should be accurate since correct registration is required for the transfer of payments by the social insurance scheme.

We aggregated data on sickness absence over the 12 months following the survey. Registry information of sickness absence was linked to the survey data by the unique 11-digit national individual identity number. The time period the employees were eligible for sickness absence was considered the same for all respondents within each company, starting from the day the electronic forms were closed. The registry was checked for inconsistencies. Overlapping or duplicate spells of sickness absence were merged.

Statistical analysis

Data were analyzed with Stata 15.1 (StataCorp, College Station, TX, USA). Risk ratios (RR), incidence rate ratio (IRR) and 95% confidence intervals (CI) were calculated with a negative binomial hurdle (NBH) model. The NBH model is capable of capturing both over-dispersion and excess of zero-values (11) and allows for analysis of data in a two-part process. First, a log-binomial regression analysis estimates the RR of having >1 day of medically certified sickness absence. Second, a zerotruncated negative binomial analysis produces IRR for the number of days absent among the sub-sample having medically certified sickness absence. Interaction analyses were conducted to determine whether the associations between office design and sickness absence were moderated by the following demographical factors: gender, age, having leadership responsibility, and educational level. All analyses were adjusted for survey year. In order to determine the impact of non-independency of observations due to cluster sampling, analyses were conducted both with and without adjustment for organizational affiliation.

Results

Demographic characteristics of participants by office type are presented in table 1. Altogether 56.5% of the sample worked in a cellular office, 27.1% worked in a shared office, and 16.5% worked in an open plan workspace. Based on official registry data, 38.8% of the sample had medically certified sickness absence during the 12 months following the survey. The average number of days with absence the year following the survey was 21.65 [standard deviation (SD) 61.40; median=0; mode=0, range 0-365). Table 1 displays the findings from the NBH model on direct effects of office design on subsequent medically certified sickness absence. Adjusting for survey year (RR 0.99, 95% CI 0.98-1.00), employees working in a shared office (RR 1.18, 95% CI 1.10-1.27), and an open-plan workspace (RR 1.12, 95% CI 1.02-1.22) had significantly higher risk of having had >1 instance of medically certified sickness absence when compared to employees working in a cellular office. Type of office design was not related to the number of sickness absence days.

Analyses were replicated with adjustment for organizational affiliation. The findings were consistent with the main analyses. Employees working in a shared office (RR 1.18, 95% CI 1.10-1.27) had a significantly higher risk of having medically certified sickness absence compared to employees working in cellular offices, whereas the difference in risk of absence between open-plan workspaces and cellular offices was borderline significant (RR 1.12, 95% CI 1.00-1.26) after adjusting for organizational affiliation. Office design was unrelated to the number of days with the absence also when adjusting for organizational affiliation.

Sensitivity analyses with shared offices and openplan workspaces, respectively, as reference groups confirmed that employees in shared offices and openplan offices had a significantly higher risk of absence compared to employees in cellular offices. There were no differences in absence risk between employees in shared offices and open plan workspaces (see supplementary material, www.sjweh.fi/show_abstract. php?abstract_id=3859).

A series of interaction analyses were conducted to determine whether the magnitude of the associations between office design and sickness absence were conditioned by demographical background variables. The results from these analyses showed no significant interaction effect between office design and gender, age, having leadership responsibility, and educational level as moderator variables with regard to risk of, and number of days with, sickness absence.

Discussion

The results from this registry-based study show that, compared to employees working in cellular offices, those working in shared offices and open-plan workspaces have an 18% and 12% higher risk, respectively, of medically certified sickness absence. There were no differences in the number of days of sickness absence between the office designs.

The magnitude of the associations were consistent across several demographic factors, indicating that shared offices and open-plan workspace designs are associated with higher risk of sickness absence irrespective of age, gender, leadership responsibility, and educational level. The findings are in line with previous studies that have found significant associations between office design and self-reported sickness absence (7, 8), and suggest that the use of shared offices and open-plan workspace designs may be considered as risk factors for sickness absence. Although shared workspaces may be cost-effective in some areas, the increased risk of sickness absence in shared- and open-plan offices suggests that employers, employees, and society in general may be paying a significant price in the form of more health problems and higher absence rates (9).

The prospective study design, large sample size, and use of official registry data to measure sickness absence are strengths of this study. As data was collected over several years (organizations participated at different time-points between 2004-2014, but all employees within the same organization responded at the same time and their data were analysed in a 12-month period consistent with the registry data), we can be relatively sure that factors such seasonal variation and economic trends had little impact on the examined associations. There were no changes in national regulations of sickness benefits during the survey period that would have influenced our findings. While the mode and the median values for days of absence were zero, the arithmetic mean was 21.65 days. This relatively high value indicate that the overall mean, as compared to mode and median values, could be inflated due to inclusion of some respondents with long-term absence. Although the survey had a response rate in correspondence with the estimated average for organizational surveys (12), altogether 52% of invited respondents did not participate to the questionnaire survey. The external validity of the findings may therefore be questioned. While the sample was large, the non-random recruitment of participating organizations limits the external validity of the findings. However, there was probability sampling at the individual level as all employees in the participating organizations were invited to participate in the survey (13).

Another limitation of this study is that we did not have access to information about number of employees sharing offices or workspaces, diagnoses for sickness absence, and the length of each absence incidence. Results with stronger validity would have been obtained if this kind of information had been included in the analyses.

This kind of information could have important practical implications and should therefore be included in future studies on the associations between workspace design and sickness absence. Previous research has established organizational characteristics, such as ethical culture, as a risk factor for sickness absence (14). In the current study, the findings of shared offices and open-plan workspaces as predictors of sickness absence remained consistent after adjusting for the respondent's organizational affiliation, thus indicating that the established associations were consistent across the participating organizations. Although we found that the associations between office design and absence were consistent across some demographical factors and organizational affiliation, it is likely that other factors, such as specific psychological, social, and physical factors (15-17), type of occupation, and the personality characteristics of the workers, could influence the magnitude of the associations. Despite these limitations, our findings indicate that shared offices and open-plan workspace designs are associated with an increased risk of medically certified sickness absence when compared to cellular offices. Providing employees with the opportunity to use cellular offices may therefore be beneficial with regard to reducing sickness absence rates.

Acknowledgements

The authors thank Bjørn Lau, Anne Lene Andersen, Shahrooz Elka, Margrethe Schøning, Elisabeth Petersen, Jan Olav Christensen, and Jan Shahid Emberland for their assistance in the survey administration. We also thank Anne-Marthe Rustad Indregard and Solveig Tobie Glestad Christiansen for the preparation of the registry data.

Funding

This study was part of a project funded by the Norwegian Research Council. Grant number: 23778.

Conflicts of interest

The authors declare no conflicts of interest.

Sidebar

Little is known about how office design influences the health, well-being, and workability of employees. Using official registry data on sickness absence, this study shows that employees working in shared- and open-plan offices have a significantly higher risk of having medically certified sickness absence compared to employees working in cellular offices.

Affiliation: National Institute of Occupational Health, PB 8149 Dep, N-0033 Oslo, Norway. morten.nielsen@stami.no

Refers to the following texts of the Journal: 2011;37(5):402-410 2018;44(3):291-302 2011;37(5):376-382

Key terms: cellular office; health; health; medically certified sickness absence; office design; open office; open-plan office; registry data; shared office; shared workstation; sick leave; sickness absence; sickness absence; workability

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31647108

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Nielsen MB, Knardahl S. The impact of office design on medically certified sickness absence. Scand J Work Environ Health. 2020;46(3):330-334. doi:10.5271/sjweh.3859

Correspondence to: Morten Birkeland Nielsen, National Institute of Occupational Health, PB 8149 Dep, N-0033 Oslo, Norway. [E-mail: morten.nielsen@stami.no]

Footnote

1 National Institute of Occupational Health, Oslo, Norway.

References

References

1. Myerson J, Bichard JA. New Demographics New Workspace Office Design for the Changing Workforce. London: Routledge; 2010.
2. Leder S, Newsham GR, Veitch JA, Mancini S, Charles KE. Effects of office environment on employee satisfaction: a new analysis. Build Res Inform 2016 Jan;44(1):34-50. https://doi.org/10.1080/09613218.2014.1003176.
3. Gjerland A, Soiland E, Thuen F. Office concepts: A scoping review. Build Environ 2019 Oct;163. https://doi. org/10.1016/j.buildenv.2019.106294
4. Engelen L, Chau J, Young S, Mackey M, Jeyapalan D, Bauman A. Is activity-based working impacting health, work performance and perceptions? A systematic review. Build Res Inform 2019 May;47(4):468-79. https://doi.org/ 10.1080/09613218.2018.1440958.
5. Richardson A, Potter J, Paterson M, Harding T, TylerMerrick G, Kirk R et al. Office design and health: a systematic review. N Z Med J 2017 Dec;130(1467):39-49.
6. De Croon EM, Sluiter JK, Kuijer PP, Frings-Dresen MH. The effect of office concepts on worker health and performance: a systematic review of the literature. Ergonomics 2005 Feb;48(2):119-34. https://doi.org/10.108 0/00140130512331319409.
7. Bodin Danielsson C, Chungkham HS, Wulff C, Westerlund H. Office design's impact on sick leave rates. Ergonomics 2014;57(2):139-47. https://doi.org/10.1080/00140139.2013 .871064.
8. Pejtersen JH, Feveile H, Christensen KB, Burr H. Sickness absence associated with shared and open-plan offices-a national cross sectional questionnaire survey. Scand J Work Environ Health 2011 Sep;37(5):376-82. https://doi. org/10.5271/sjweh.3167.
9. Steensma H. Sickness absence, office types, and advances in absenteeism research. Scand J Work Environ Health 2011 Sep;37(5):359-62. https://doi.org/10.5271/sjweh.3185.
10. Nielsen MB, Christiansen S, Indregard AM, Emberland JS, Elka S, Knardahl S. The new workplace II: protocol for a prospective full-panel registry study of work factors, sickness absence, and exit from working life among Norwegian employees. Springerplus. 2016;5(243). https://doi. org/10.1186/s40064-016-1896-z.
11. Mullahy J. Specification and Testing of Some Modified Count Data Models. J Econom 1986 Dec;33(3):341-65. https://doi.org/10.1016/0304-4076(86)90002-3.

12. Baruch Y, Holtom BC. Survey response rate levels and trends in organizational research. Hum Relat 2008;61(8):1139-60. https://doi.org/10.1177/0018726708094863.
13. Ilies R, Hauserman N, Schwochau S, Stibal J. Reported incidence rates of work-related sexual harassment in the United States: using meta-analysis to explain reported rate disparities. Person Psychol 2003;56(3):607-31. https://doi. org/10.1111/j.1744-6570.2003.tb00752.x.
14. Kangas M, Muotka J, Huhtala M, Makikangas A, Feldt T. Is the Ethical Culture of the Organization Associated with Sickness Absence? A Multilevel Analysis in a Public Sector Organization. J Bus Ethics 2017 Jan;140(1):131-45. https:// doi.org/10.1007/s10551-015-2644-y.
15. Christensen JO, Nielsen MB, Finne LB, Knardahl S. Comprehensive profiles of psychological and social work factors as predictors of site-specific and multi-site pain. Scand J Work Environ Health 2018 May;44(3):291-302. https://doi.org/10.5271/sjweh.3706.
16. Emberland JS, Nielsen MB, Knardahl S. Psychological, social, and mechanical work exposures and disability retirement: a prospective registry study. BMC Public Health 2017 Jan;17(1):56. https://doi.org/10.1186/s12889-0163921-0.
17. Danielsson CB, Theorell T. Office Employees' Perception of Workspace Contribution: A Gender and Office Design Perspective. Environ Behav 2019;51(9-10):995-1026. https://doi.org/10.1177/0013916518759146.
Received for publication: 29 July 2019

DETAILS

Subject:	Employee benefits; Age; Leadership; Confidence intervals; Studies; Offices; Questionnaires; Risk factors; Office layout; Workstations; Design; Workability; Risk analysis; Sick leave; Employees; Polls &surveys
Business indexing term:	Subject: Sick leave Employees
Location:	Norway
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	330-334,330A
Publication year:	2020
Publication date:	2020
Section:	Short communication
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm

Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3859
ProQuest document ID:	2406986723
Document URL:	https://www.proquest.com/scholarly-journals/impact-office-design-on-medically-certified/docview/2406986723/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2022-04-29
Database:	Public Health Database

Document 3 of 12

Applying two general population job exposure matrices to predict incident carpal tunnel syndrome: A cross-national approach to improve estimation of workplace physical exposures

Yung, M; Evanoff, B A [1]; Buckner-Petty, S; Roquelaure, Y; Descatha, A; Dale, A M [1] Division of General Medical Sciences, Washington University School of Medicine in St Louis, St Louis, MO 63110, USA

ProQuest document link

ABSTRACT (ENGLISH)

Objectives A job exposure matrix (JEM) is a tool to estimate workers' exposure to occupational physical risk factors. We evaluated the performance of two general population JEM (CONSTANCES and O·NET) to detect known exposure-disease relationships in an American prospective cohort study. We compared exposure estimates from three data sources and explored whether combining exposures from these two JEM, or combining exposure from each JEM with individual-level measures, improved prediction of carpal tunnel syndrome (CTS).

Methods Using Cox proportional hazard models, we evaluated relationships between physical work exposure and incident CTS of 2393 workers using JEM-assigned and individual-level measure exposure information. We

compared exposure estimates using Spearman's rank correlation and Cohen's kappa. We compared combined exposure models to single source exposure models by using binomial logistic regression and examined differences based on model fit and performance.
Results The O·NET JEM [hazard ratio (HR) range 1.3-2.01] demonstrated generally similar exposure-disease associations as individual-level measures (HR range 1.00-1.42); we found fewer associations with the CONSTANCES JEM (HR range 1.08-2.05). Comparisons between the three sources showed stronger correlations and agreement at the job versus worker level. Combined models improved goodness-of-fit and had lower Akaiké information criterion (AIC) values compared to single-source models.
Conclusions JEM can be applied cross nationally and there is potential to combine complementary exposure methods to improve estimation of workplace physical exposures in the prediction of CTS. More investigations are needed to explore exposure-disease associations in other samples and combinations of exposure data from different methods.

FULL TEXT

Headnote

Objectives A job exposure matrix (JEM) is a tool to estimate workers' exposure to occupational physical risk factors. We evaluated the performance of two general population JEM (CONSTANCES and O·NET) to detect known exposure-disease relationships in an American prospective cohort study. We compared exposure estimates from three data sources and explored whether combining exposures from these two JEM, or combining exposure from each JEM with individual-level measures, improved prediction of carpal tunnel syndrome (CTS).
Methods Using Cox proportional hazard models, we evaluated relationships between physical work exposure and incident CTS of 2393 workers using JEM-assigned and individual-level measure exposure information. We
compared exposure estimates using Spearman's rank correlation and Cohen's kappa. We compared combined exposure models to single source exposure models by using binomial logistic regression and examined differences based on model fit and performance.
Results The O·NET JEM [hazard ratio (HR) range 1.3-2.01] demonstrated generally similar exposure-disease associations as individual-level measures (HR range 1.00-1.42); we found fewer associations with the CONSTANCES JEM (HR range 1.08-2.05). Comparisons between the three sources showed stronger correlations and agreement at the job versus worker level. Combined models improved goodness-of-fit and had lower Akaiké information criterion (AIC) values compared to single-source models.
Conclusions JEM can be applied cross nationally and there is potential to combine complementary exposure methods to improve estimation of workplace physical exposures in the prediction of CTS. More investigations are needed to explore exposure-disease associations in other samples and combinations of exposure data from different methods.
Key terms assessment injury prevention; CTS; ergonomics; exposure-risk; JEM; job exposure matrix; musculoskeletal disorder; MSD; occupational health; risk.

Workplace exposure assessment is necessary for effective assessment and prevention of health conditions that may be affected by occupational factors including physical (biomechanical) exposures. A job exposure matrix (JEM) is an efficient tool to estimate workers' exposure to occupational risk factors by using job titles, industry information, and job-level exposure data. There has been considerable international interest in constructing JEM to estimate physical exposures for the study of workrelated musculoskeletal disorders (MSD), leading to recent JEM created in Denmark (1), Norway (2), Finland (3, 4), the United States (5, 6), and France (7).

Several studies have validated physical exposure JEM and their association with various MSD, including low-back pain (3), hip and knee osteoarthritis (8, 9), carpal tunnel syndrome (CTS) (10), and subacromial impingement syndrome (11). More recently, we (12) validated a JEM (O·NET JEM) based on the American Occupational Information Network data (O·NET, www. onetonline.org) by comparing exposure-disease asso1 ciations for incident CTS in a well-studied cohort of US workers (13). Exposure-disease associations obtained using physical exposures estimated from a JEM were similar to associations obtained from observations of individual workers (12). In a cross-national comparison of exposure estimates, we compared a French JEM based on self-reported physical exposures from a large cohort study (CONSTANCES - Cohorte des consultants des Centres d'examens de sante) (14, 15) with the American O·NET JEM based on exposure information provided by expert job analysts and from surveys of workers in different jobs. We found that exposure estimates from these two general population JEM were strongly related, suggesting that results obtained from different general population JEM were likely to be comparable. In some circumstances, it might be reasonable to combine exposures from different JEM to provide better estimates of some exposures (16).

The objectives of this study were to evaluate the ability of the CONSTANCES and O·NET JEM to detect known exposure-disease relationships in a large US prospective cohort study and to explore whether combining exposure variables from multiple sources of exposure information improved the prediction of health outcomes (figure 1). As an extension of our previous study (12), we first evaluated the predictive validity of the CONSTANCES and O·NET JEM by testing their ability to reproduce known exposure-disease associations obtained from individual-level measures (Aim 1). To further examine the relationships between the three sources of exposure data, we then compared associations and agreement of exposure estimates between the CONSTANCES JEM, the O·NET JEM, and individual-level measures obtained from a large US prospective cohort study (Aim 2). Finally, we compared multivariable models combining exposure data from both JEM and observations to determine whether a combined exposure variable model predicted CTS better than a model containing exposure data from a single source (Aim 3). To our knowledge, this is the first study to explore the combination of exposure variables from two general population JEM and individual-level measures in the prediction of MSD. A general population JEM that produces similar exposure-disease associations to individual-level measures, and which can serve as a strong complement to existing JEM, will be an effective tool to study the effects of workplace physical exposures on a variety of health conditions.

Methods

Individual-level measures

Cohort study methodology. Pooled exposure data were obtained from six prospective cohort studies conducted as part of the NIOSH upper-extremity MSD consortium. This cohort has been thoroughly described in previous studies (12, 13, 17-19). In brief, 4321 workers were recruited across six study sites and followed between 2001 and 2010. All study participants were full-time employees, >18 years of age, recruited from jobs that involved hand-intensive activities, and employed in manufacturing, production, service, and construction industries. Ethics approval was provided by the respective institutional review boards for each study and written informed consent was obtained from all participants.

Both hand/arm exposures and the health outcome (CTS) were assigned at the worker level. All study participants completed baseline questionnaires and underwent physical examinations, which included median and ulnar nerve electrodiagnostic tests. We defined incident CTS as (i): symptoms of tingling, numbness, burning or pain in the thumb, index finger or long finger, and (ii) abnormal electrodiagnostic tests consistent with median neuropathy at the wrist (12). Work exposure assessments were performed for each individual, consisting of interviews to identify primary work tasks, video recordings of workers performing typical work tasks, and workerand analyst-rated estimation of hand forces required to perform each task. Physical exposure variables were relevant to MSD risk, including force, repetition, hand/ wrist posture, and hand/arm vibration.

Individual-level measure variables. Peak hand force required for a task was assessed using the Borg category ratio 0-10 (CR-10) rating scale (20) and was obtained from both worker estimates [peak hand force (worker rated)] and from trained analysts [peak hand force (analyst rated)]. Video recordings of work tasks provided estimates of duty cycle, for all exertions in a task (duty cycle for all exertions) or for exertions requiring significant force (duty cycle of forceful exertions). Forceful exertions were defined as pinch force >9 N, or power grip force >45 N, or a Borg CR-10 rating of >2; estimates of force was based on measurement of the force required for the task, the weights of parts or tools, or from force matching. Repetitiveness of tasks were estimated using hand activity level (HAL) ratings, which were calculated using Latko et al's (21) 0-10 verbal anchor scale determined by analysts who assigned ratings by observation in the field and from video analysis of worker tasks. Other temporal exertion patterns for repetition was determined by detailed time studies of video recordings for all exertions (repetition per minute for all exertions) and for significant exertions (repetition per minute for forceful exertions). The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for HAL was calculated to provide a single composite index value from a combination of job physical exposure factors (force and repeti- tion) (22). Both worker- and observer-estimated TLV were calculated using the equation score of TLV = peak force/(10-HAL), using worker- or analyst-rated peak force, and the analyst-rated HAL. Finally, using video recordings of work tasks, we calculated the percentage of time in wrist extension (>50 degrees) or flexion (>30 degrees). Workers who performed multiple tasks in their job, or their supervisors, provided estimates of the proportion of time spent in each task. We calculated a time-weighted-average (TWA) exposure to create a single exposure variable measure that accounted for the proportion of daily work time in each observed task.

CONSTANCES job exposure matrix. A general population physical exposure JEM was constructed from selfreported data obtained from CONSTANCES, a large cohort study of French salaried workers (14, 15). Details of the creation of this JEM have been described in Evanoff et al (7). Briefly, in CONSTANCES, the duration of performing specific activities of a given frequency or intensity were self-reported for the current job using a 4- or 5-point ordinal scale; physical intensity was assessed with Borg's rating of perceived exertion (RPE) scale. The CONSTANCES JEM focused on 27 physical risk factors relevant to MSD and used data from the first 81 425 CONSTANCES participants. Reported job titles were assigned a 4-digit PCS (profession et categorie sociale - profession and social category) job code using the SiCore automated coding system (23). When required, job codes were grouped with similar codes to ensure all PCS job codes had a minimum of ten valid responses for each of its 27 physical risk factors. The resulting JEM was comprised of 27 physical risk factors assigned to 407 different 4-digit PCS codes among 35 526 eligible CONSTANCES participants after excluding participants who (i) were not currently working, (ii) did not report a job title, (iii) were not assigned a PCS job code through automatic coding, or (iv) had missing exposure data.

O·NETjob exposure matrix. A JEM was created using physical job demand data obtained from O·NET (version 21.2), a publicly available American database of more than 800 occupations. Estimates of job demands, pertaining to the frequency and intensity, were provided by expert job analysts and from self-reported exposures by individual workers across different jobs. Job demands in O·NET were scored on a 5- or 8-point ordinal scale with exposure-specific descriptive anchors (16). Occupations from O·NET were assigned a standard occupational classification (SOC) job code.

Assigning JEM exposure estimates to individual workers

From the 4321 original pooled consortium study cohort, we excluded prevalent cases of CTS at baseline and removed subjects with no follow-up measurements, workers who did not have detailed data necessary for individual assessment, and workers who had missing covariate data, leaving 2393 workers for analysis of CTS incidence. This analyzed cohort was identical to a previous study on exposure-disease associations that used a smaller set of O·NET exposure variables (12). SOC codes were assigned to each job for each worker using information about the worker's current job (ie, job title, company name, job start date and work-related tasks) collected at baseline (12). The job title selection feature provided by O·NET assisted in assigning SOC codes to match primary tasks reported by the worker and from employer information. Two raters, blinded by case status, assigned job codes independently, with differences resolved by consensus. For assigning exposure values using the CONSTANCES JEM, we created a crosswalk to match French PCS codes with American SOC codes based on similarity of work physical exposures (16). French PCS codes were first matched to three-digit ISCO-88 (International Standard Classification of Occupations) codes using the Codage Assisié des Professions ei Secieurs d'aciiviié (CAPS) and an existing French auto-coding tool (24). ISCO-88 codes were then matched to ISCO-08 codes using an existing crosswalk from the International Labour Organization (25). Finally, ISCO-08 codes were matched to American SOC codes using an existing crosswalk from the US Bureau of Labor Statistics (www.bls.gov/soc). The mean CONSTANCES ordinal score for each exposure variable was then assigned to each participant's SOC code. A similar process was performed when assigning exposure values using the O·NET JEM. The mean O·NET ordinal score for each exposure variable was assigned to each consortium participant. For every exposure variable, each of 2393 participants was assigned an exposure value from the individual-level measures, an exposure estimate from the CONSTANCES JEM, and an exposure estimate from the O·NET JEM. We focused on exposures relevant to incident CTS: 11 exposure variables from the CONSTANCES JEM, 8 variables from the O·NET JEM, and 11 variables from the consortium study (supplementary material: www. sjweh.fi/show_abstract.php?abstract_id=3855 tables S1 and S2). Variables such as "stand" and "work outdoors" were excluded from analysis as they were not expected to be related to CTS. Dale et al (12), reported exposure-disease associations for CTS using a subset of physical exposures from O·NET (12); in this study we examined a larger set of O·NET variables.

Statistical analysis

Aim 1: Physical exposures and incident CTS. We computed Cox proportional hazard models to evaluate relationships between baseline physical work exposure and incident CTS. We determined hazard ratios (HR) and 95% confidence intervals (Cl) adjusted for age, gender, body mass index (BMI), and study site. Each model included a single physical work exposure from the CONSTANCES JEM, O·NET JEM, or individual-level measurement. Since exposure data from all sources were expressed on different scales, we examined a dichotomous exposure model where values were split at the median value (high versus low), in addition to continuous exposure models (per 1-unit increase). We applied robust sandwich estimators (26) to account for intra-cluster dependence within each model.

Aim 2: Comparison of exposure estimates between JEM and individual-level measures and between JEM at the workerandjob-level. We carried out two comparison analyses: Spearman's rank correlation coefficient and Cohen's kappa. We matched a priori similar exposure variables in order to compare exposure estimates between JEM and observation. Matched exposure variables assessed similar ergonomic risk factors (ie, force, repetition, posture, duration). For the O·NET JEM, we matched >1 of 8 0·NET variables to 11 consortium variables, resulting in 41 matched pairs (supplementary table S1). For the CONSTANCES JEM, we matched >1 of 9 CONSTANCES variables to 11 consortium variables, resulting in 54 matched pairs (supplementary table S2). Between CONSTANCES and O·NET JEM, we matched 8 O·NET variables with 9 CONSTANCES variables, resulting in 28 matched pairs (16). Job title data represented 130 unique American SOC codes matched to 77 unique French PCS codes.

We assigned exposure values from both JEM and from individual-level measurement to each of 2393 workers, and calculated Spearman correlations and Cohen's kappa at the worker level between: (i) O·NET JEM and consortium exposures, (ii) CONSTANCES JEM and consortium exposures, and (iii) CONSTANCES and O·NET JEM. We also performed the same comparisons at the level of the job within the 130 job codes contained in the consortium data. When calculating Cohen's kappa, we dichotomized physical exposure estimates from the CONSTANCES JEM, O·NET JEM, and consortium individual-level measure exposure data at their respective median physical exposure levels. We interpreted our Cohen's kappa calculation as the level of agreement in categorizing high and low exposure groups between exposure methods for each paired exposure variable.

Aim 3: Comparison of models consisting of CONSTANCES, O·NET, and individual-level measures in predicting incident CTS. Our third aim was to compare models based on their performance, including measure of goodness-of-fit. In order to compare models, we used binomial logistic regression with research site as a random intercept; there are few readily implemented tests for goodness-of-fit for Cox proportional hazard models (27). Each model included a set of physical work exposures from the CONSTANCES JEM (11 variables), O·NET JEM (8 variables), and consortium individual-level measures (11 variables). For all binomial logistic regression models, we selected a fixed follow-up time of two years for all participants; this two-year period ensured that data from all six study sites were retained in our analysis, leaving 2173 eligible participants for analysis. We excluded all participants who had missing exposure data, leaving 1073 participants.

For the multivariable model analysis, we performed backward selection by Akaike information criterion (AIC) (28), to retain a subset of variables, adjusted for age, gender, BMI, and research site, for models containing CONSTANCES, O·NET, or consortium exposures. For each model, we calculated the c-statistic as a measure of goodness-of-fit of

models with multiple variables from each exposure method.
To explore the prediction of incident CTS by combining variables across JEM or adding JEM data to individual-level measures, we compared an O·NET-only model to O·NET + CONSTANCES, and a consortium exposure-only model to consortium + O·NET and consortium + CONSTANCES. For these combined models, we carried out backward selection by AIC, retaining a subset of JEM variables into a model with our a priori selected covariates (age, gender, BMI, research site) and 0·NET or consortium variables identified in the 0·NET or consortium variable-only analysis. We computed AIC estimates (29), and the c-statistic, between the O·NET model and CONSTANCES + O·NET model, between the consortium model and consortium + O·NET model, and between the consortium model and consortium + CONSTANCES model. We compared c-statistics by calculating the 95% CI with bootstrapping resulting in a one-sided bootstrapped P-value.
All analyses were carried out with R software (R Foundation for Statistical Computing, Vienna, Austria).
Results
Aim 1: Physical exposures and incident CTS
HR for consortium individual-level measures ranged from 1.00-1.42 for continuous models. Of 11 consortium exposure variables, 9 were statistically meaningful, with the highest HR value observed with ACGIH TLV (analyst rated). In analyzing the dichotomous models, 5 exposure variables were statistically meaningful.
All 8 O·NET variables were statistically meaningful in their relationship to incident CTS. HR ranged from 1.31 (95% CI 1.01-1.70) (wrist finger speed) to 2.01 (95% CI 1.55-2.59) (spend time using your hands) in the continuous models. We observed HR ranging from 0.99-1.64 in the dichotomous models where 4 variables were statistically significant.
HR from continuous models were in the range of 1.08-2.05 for CONSTANCES exposure variables (table 1). Of 11 variables, only 2 were statistically meaningful. "Finger pinch" demonstrated the highest HR of 2.05 (95% CI 1.38-3.06), followed by "rotate forearm" (HR 1.44, 95% CI 1.10-1.89). Dichotomous models showed HR between 0.81-1.46, only "repetition" was statistically significant.
In summary, we observed significant exposure-disease associations using O·NET JEM exposure variables to predict CTS in a US worker population; these associations were broadly similar to variables assessed by individual-level measures. We also observed some, but fewer, significant exposure-disease associations using a CONSTANCES JEM to predict CTS in a US worker population.
Aim 2: Comparison of exposure estimates between JEM and individual-level measures and between JEM at the worker- and job-level
Aim 2 results are reported in supplementary figures S1-4. We provide an example that is indicative of overall trends and briefly describe the supplementary results. In our example, correlation coefficients between worker-assigned CONSTANCES JEM and consortium individual-level measure exposure variables ranged from -0.01 to 0.36 (figure 2a). Among the 54 matched pairs, 9 pairs demonstrated low positive correlations while the remaining 45 pairs were negligibly correlated. Unmatched pairs resulted in negligible-to-low correlations. Between CONSTANCES and consortium variables, Cohen's kappa values ranged between -0.07 and 0.37 (figure 2b). Of the 54 matched pairs between CONSTANCES and individual-level measures, 17 pairs demonstrated fair agreement. Unmatched exposure variable pairs showed low-to-fair agreement.
We also compared O·NET and CONSTANCES JEM exposure variables with consortium individuallevel measures at the job level for 130 SOC job codes. Between CONSTANCES and consortium estimates, correlations ranged between 0.06 (negligible) and 0.59 (moderate). Of 54 matched pairs, 27 were moderately correlated (figure 3a). Between CONSTANCES JEM and consortium individual-level measures, 23 matched pairs demonstrated moderate agreement (figure 3 b). Cohen's kappa values ranged between -0.02 and 0.51.
In our results, we found mostly low correlations and slight agreement between matched variables from the O·NET JEM and consortium individual-level measures when assigned to workers (supplementary figures S1a-b). Comparing CONSTANCES and O·NET JEM exposure estimates assigned to workers, the correlations between matched variables were minimal but agreement was fair to moderate (supplementary figure S2a-b). When

comparing exposure estimates at the job level, correlation and agreement between CONSTANCES JEM, O·NET JEM, and individual-level measure variables were substantially higher (supplementary figures S3a-b and S4a-b).

Aim 3: Comparison of models consisting of CONSTANCES, O·NET, and individual-level measures in predicting incident CTS

The analyzed cohort from aims 1 and 2 was compared to aim 3's restricted sample. We observed similar mean age and BMI between the two analyzed samples (supplementarey table S3), however, the restricted sample had a larger proportion of female workers (60.4% versus 52.2%) and a higher incident rate of CTS (4.8 cases per 100 person-years versus 3.9 cases per 100 personyears). The number of SOC job codes represented within the analyzed cohort decreased from 130 SOC codes in the aim 1 and 2 sample to 113 SOC codes in the aim 3 sample; the proportion of workers per job code in each sample showed little difference, with a maximum of 5% (supplementary table S4). Between the two samples, mean physical exposure levels for the 11 consortium variables were similar (supplementary table S5).

We also compared exposure-disease associations between the aim 1/aim 2 full, and aim 3 restricted samples. We computed log-binomial regression odds ratios (OR) for each variable within the three sources of exposure data (supplementary table S6). Generally, in both full and restricted samples, we observed statistically meaningful relationships between exposure variables, within each of the three sources of data, and incident CTS.

Backward selection based on AIC resulted in three retained variables in each of CONSTANCES, 0·NET, and consortium models (table 2). We also listed the exposure variables within each combined variable model and compared their performance against a single source model (table 2). For example, the O·NET + CONSTANCES model consisted of five CONSTANCES variables added to the three O·NET job demands. When compared to the O·NET variable-only model, the O·NET + CONSTANCES model had a significantly higher c-index (P=0.02) and a lower AIC (A=-13.0). We observed similar trends with the combined consortium + O·NET and consortium + CONSTANCES models where c-indices were significantly higher (P=0.01 and P=0.02, respectively) and the AIC values were lower (Д=-16.6 and Д=-10.30, respectively) from the single source model.

In summary, combining exposure variables from two sources of exposure information improved model performance compared to a single source of exposure information. Combining CONSTANCES JEM variables with O·NET JEM variables better predicted CTS than a model of only O·NET variables. Combining either CONSTANCES JEM or O·NET JEM exposure variables with individual-level measures also improved model performance.

Discussion

There is a growing interest in applying physical exposure JEM to improve prediction of MSD and other health conditions by incorporating exposure variables to cohorts where no other work exposure data exists, or complementing existing sources of exposure information by combining exposure methods. There is also interest in comparing results obtained from JEM developed in different countries. We observed meaningful exposure-disease associations with incident CTS in a US worker population using both the American O·NET and the French CONSTANCES JEM, with a greater number of associations found with the O·NET JEM. Combining exposures from two JEM or combining exposure from a JEM with individual-level measures improved the prediction of CTS in exploratory models.

We previously evaluated a subset of O·NET exposure variables and their relationship with incident CTS (12) and found that O·NET JEM exposure estimates predicted CTS with similar effect sizes as exposure values obtained from individual-level measurement. In this study, we extended this evaluation by including three additional 0·NET variables and found similar significant exposure-disease associations using O·NET JEM exposure estimates, particularly with variables related to strength and job demands requiring hand motions. We also evaluated the French CONSTANCES JEM, which includes physical exposures not available through O·NET, including pinch grip, hand or wrist posture, and hand vibration. CONSTANCES exposure variables pertaining to repetition were statistically meaningful in both continuous and dichotomous survival analysis models, while "rotate forearm" and "use vibrating tools" were statistically meaningful predictors in log binomial analyses. Differences between 0·NET and CONSTANCES questions and scales might help explain contrasts in the exposure-disease associations between seemingly similar exposure variables. Generally, O·NET variables address the magnitude or intensity of exposure whereas CONSTANCES variables pertain to duration of performing specific actions at a specific intensity or frequency.

Although we observed meaningful exposure-disease associations with incident CTS using CONSTANCES and O·NET JEM, we observed negligible-to-low correlations and low-to-fair agreement between individuallevel measures and both JEM. These results, in part, likely reflected the different scales and methods used to obtain exposure data from CONSTANCES, O·NET, and the consortium study. We previously found moderate-tohigh positive correlations and moderate-to-substantial agreement between CONSTANCES and O·NET exposure variables at the job level for 367 job codes (16); in that analysis, each job code was weighted equally. In the current study, we observed higher correlations and agreement between JEM exposure estimates when comparing agreement at the job level than when comparing agreement at the worker level; when assigning exposure estimates at the worker level, correlations and agreement are dependent on the distribution of workers in different jobs within the population. In order to compare with worker level observation, the current study also compared a smaller number of job codes (130 SOC codes and 77 PCS codes) than the previous CONSTANCES to O·NET comparison (367 job codes). The strength of agreement between JEM and other exposure estimates may be influenced by the distribution of the worker population and the number of jobs under study; both of these factors may affect the within-job versus betweenjob variation in JEM-based exposure estimates.

Differences in constructs between general population JEM provide an opportunity to combine complementary variables into a single multivariable model. Hybrid exposure assessment methods have been used to study prostate cancer risk (30) and shoulder disorders (1). Since the development of MSD is multifactorial (31), relying on a single source of exposure information may not provide the optimal breadth of physical exposure data, and hybrid exposure methods offer the opportunity to improve precision while maintaining the efficiency of a JEM. Our exploratory comparison of multivariable exposure models supports the use of combining data obtained from individual-level measures with JEM data, and combining data from different JEM. Combining exposure variables from a French population JEM with an American JEM to predict CTS in a US worker population improved model performance. Combining JEM variables with individual-level measures also seemed to improve the prediction of incident CTS. We observed decreases in AIC compared to the baseline model, indicating that combined variable models provided better approximations than single source models (29). These findings warrant further research in combining exposure data from different methods to better predict risks of work-related MSD.

Alongside our study strengths, there are several limitations. First, we used a sample size of 2393 workers for aims 1 and 2, allowing for comparisons using the widest range of available job codes and time-to-event analysis; in aim 3, we used a restricted sample of 1073 workers in order to compare predictive models. Despite slight differences in demographics, incidence rate of CTS, and fewer SOC codes represented within the restricted sample, the mean physical exposure levels between the two samples were similar. Second, the crosswalk process for matching French PCS codes with American SOC codes required a multistep process. Existing software and tools assisted with assignment of job codes; however, there is no certainty that crosswalked jobs have the same tasks with similar exposures, nor that job tasks performed in identical jobs in different countries are the same. Furthermore, the number of job codes reflected in this analysis was on a portion of all possible job codes within each country. These differences may have contributed to the fewer exposure-disease associations found using the CONSTANCES JEM.

Overall, our results suggest that O·NET JEM and to some degree CONSTANCES JEM can reproduce known exposure-disease associations obtained from individuallevel measures. Combining exposure estimates between two JEM and between JEM and individual-level measures improved the prediction of CTS when compared to single source models. Exposure information from a JEM could potentially enrich existing individual-level datasets or complement an existing JEM that might lack particular exposures. These preliminary findings using cross-national JEM are encouraging, but clearly, more investigations are needed to explore exposure-disease associations in other samples and combinations of exposure data from different methods to better predict MSD risk.

Concluding remarks

Both O·NET and CONSTANCES JEM demonstrated meaningful exposure-disease associations with incident CTS. The O·NET general population JEM demonstrated generally similar results as individual-level measures when calculating exposure-disease associations for CTS in the same worker cohort while the CONSTANCES JEM demonstrated fewer associations for CTS. This suggests that these JEM are useful tools for estimating workplace physical exposures in population studies. In exploratory models, adding exposure data from JEM to individuallevel measures improved the prediction of incident CTS in our study, as did combining data from JEM from two different countries. These data suggest potential for combining exposure methods to improve the estimation of workplace physical exposures for surveillance and epidemiology studies. The performance of a general population JEM is influenced on the distribution of jobs within the studied worker population; in most cases it is likely that a larger variability of jobs within a studied cohort will improve the ability of general population JEM to demonstrate exposure-disease associations.

Acknowledgments

This study was supported by the US National Institute for Occupational Safety and Health (NIOSH R01OH011076 and R01OH009172). The French CONSTANCES cohort is supported by the French National Research Agency (ANR-11-INBS-0002), Caisse Nationale d'Assurance Maladie des travailleurs salaries CNAMTS, and is funded by the Institut de Recherche en Santé Publique/Institut Thématique Santé Publique, and the following sponsors: Ministere de la santé et des sports, Ministere délégué a la recherche, Institut national de la santé et de la recherche médicale, Institut national du cancer et Caisse nationale de solidarité pour l'autonomie, as well as Institute for research in public health (IReSP, CapaciT project).

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of NIOSH. We would like to acknowledge the efforts of our NIOSH Upper Limb Musculoskeletal Disorder Consortium research partners (L Merlino, S Burt, MS Thiese, S Bao, AR Meyers, C Harris-Adamson, J Kapellusch, EA Eisen, F Gerr, KT Hegmann, B Silverstein, A Garg, and D Rempel) and the large number of research technicians, assistants, and any other personnel from each research study group who made the collection of data presented in this manuscript possible.

Sidebar

General population job exposure matrices (JEM) are useful tools to estimate workplace physical exposures in population studies. The French CONSTANCES JEM and American O·NET JEM demonstrated similar exposure-disease associations as individual-level directly observed exposures. JEM can be applied cross-nationally. Combining complementary variables between two JEM and between JEM and individual-level directly observed exposures improved prediction of health conditions.

Refers to the following texts of the Journal: 1993;19(2):73-84 2019;45(3):239-247

Key terms: assessment injury prevention; carpal tunnel syndrome; CTS; ergonomics; exposure-risk; incident carpal tunnel syndrome; JEM; job exposure matrix; MSD; musculoskeletal disorder; occupational health;; physical exposure; prediction; risk; workplace physical exposure

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31638705

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Yung M, Evanoff BA, Buckner-Petty S, Roquelaure Y, Descatha A, Dale AM. Applying two general population job exposure matrices to predict incident carpal tunnel syndrome: A cross-national approach to improve estimation of workplace physical exposures. Scand J Work Environ Health. 2020;46(3):248-258. doi:10.5271/sjweh.3860

Correspondence to: Dr Bradley A Evanoff, Division of General Medical Sciences, Washington University School of Medicine in St Louis, St Louis, MO 63110, USA. [E-mail: bevanoff@wustl.edu]

Footnote

1 Division of General Medical Sciences, Washington University School of Medicine, St. Louis, MO, USA.

2 INSERM, U1085, IRSET (Institute de recherché en santé, environnement et travail), ESTER Team, University of

Angers, Angers, France.
3 AP-HP, EMS (Samu92), Occupational Health Unit, Raymond Poincaré University Hospital, Garches, France.
4 INSERM, UMR 1168 UM2011, University of Versailles Saint-Quentin-en-Yvelines, Villejuif, France.
References

References

1. Dalbøge A, Hansson GA, Frost P, Andersen JH, HeilskovHansen T, Svendsen SW. Upper arm elevation and repetitive shoulder movements: a general population job exposure matrix based on expert ratings and technical measurements. Occup Environ Med 2016 Aug;73(8):553-60. https://doi. org/10.1136/oemed-2015-103415.
2. Hanvold TN, Sterud T, Kristensen P, Mehlum IS. Mechanical and psychosocial work exposures: the construction and evaluation of a gender-specific job exposure matrix (JEM). Scand J Work Environ Health 2019 May;45(3):239-47. https://doi.org/10.5271/sjweh.3774.
3. Solovieva S, Pehkonen I, Kausto J, Miranda H, Shiri R, Kauppinen T et al. Development and validation of a job exposure matrix for physical risk factors in low back pain. PLoS One 2012;7(11):e48680. https://doi.org/10.1371/ journal.pone.0048680.
4. Ervasti J, Pietiläinen O, Rahkonen O, Lahelma E, Kouvonen A, Lallukka T et al. Long-term exposure to heavy physical work, disability pension due to musculoskeletal disorders and all-cause mortality: 20-year follow-up-introducing Helsinki Health Study job exposure matrix. Int Arch Occup Environ Health 2019 Apr;92(3):337-45. https://doi. org/10.1007/s00420-018-1393-5.
5. Evanoff B, Zeringue A, Franzblau A, Dale AM. Using job-title-based physical exposures from O·NET in an epidemiological study of carpal tunnel syndrome. Hum Factors 2014 Feb;56(1):166-77. https://doi. org/10.1177/0018720813496567.
6. Dale AM, Zeringue A, Harris-Adamson C, Rempel D, Bao S, Thiese MS et al. General population job exposure matrix applied to a pooled study of prevalent carpal tunnel syndrome. Am J Epidemiol 2015 Mar;181(6):431-9. https:// doi.org/10.1093/aje/kwu286.
7. Evanoff BA, Yung M, Buckner-Petty S, Andersen JH, Roquelaure Y, Descatha A et al. The CONSTANCES job exposure matrix based on self-reported exposure to physical risk factors: development and evaluation. Occup Environ Med 2019 Jun;76(6):398-406. https://doi.org/10.1136/ oemed-2018-105287.
8. Rubak TS, Svendsen SW, Andersen JH, Haahr JP, Kryger A, Jensen LD et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014 Jun;15:204. https://doi.org/10.1186/1471-247415-204.
9. Rijs KJ, van der Pas S, Geuskens GA, Cozijnsen R, Koppes LL, van der Beek AJ et al. Development and validation of a physical and psychosocial job-exposure matrix in older and retired workers. Ann Occup Hyg 2014 Mar;58(2):152-70.
10. Gardner BT, Lombardi DA, Dale AM, Franzblau A, Evanoff BA. Reliability of job-title based physical work exposures for the upper extremity: comparison to selfreported and observed exposure estimates. Occup Environ Med 2010 Aug;67(8):538-47. https://doi.org/10.1136/ oem.2008.044339.
11. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Surgery for subacromial impingement syndrome in relation to occupational exposures, lifestyle factors and diabetes mellitus: a nationwide nested case-control study. Occup Environ Med 2017 Oct;74(10):728-36. https://doi. org/10.1136/oemed-2016-104272
12. Dale AM, Ekenga CC, Buckner-Petty S, Merlino L, Thiese MS, Bao S, et al. Incident CTS in a large pooled cohort study: associations obtained by a Job Exposure Matrix versus associations obtained from observed exposures. Occup Environ Med. 2018 Jul;75(7):501-6. https://doi.org/ 10.1136/ oemed-2017-104744.
13. Kapellusch JM, Garg A, Bao SS, Silverstein BA, Burt SE, Dale AM et al. Pooling job physical exposure data from multiple independent studies in a consortium study of carpal tunnel syndrome. Ergonomics 2013;56(6):1021-37. https:// doi.org/10.1080/00140139.2013.797112.
14. Goldberg M, Carton M, Descatha A, Leclerc A, Roquelaure Y, Santin G et al.; CONSTANCES team. CONSTANCES: a general prospective population-based cohort for occupational and environmental epidemiology:

cohort profile. Occup Environ Med 2017 Jan;74(1):66-71. https:// doi.org/10.1136/oemed-2016-103678.
15. Zins M, Goldberg M; CONSTANCES team. The French CONSTANCES population-based cohort: design, inclusion and follow-up. Eur J Epidemiol 2015 Dec;30(12):1317-28. https://doi.org/10.1007/s10654-015-0096-4.
16. Evanoff B, Yung M, Buckner-Petty S, Baca M, Andersen JH, Roquelaure Y, et al. Cross-national comparison of two general population job exposure matrices for physical work exposures. Occup Environ Med. 2019 Mar;76:567-72. https://doi.org/10.1136/oemed-2018-105408.
17. Rempel D, Gerr F, Harris-Adamson C, Hegmann KT, Thiese MS, Kapellusch J et al. Personal and workplace factors and median nerve function in a pooled study of 2396 US workers. J Occup Environ Med 2015 Jan;57(1):98-104. https://doi.org/10.1097/J0M.0000000000000312.
18. Bao SS, Kapellusch JM, Garg A, Silverstein BA, HarrisAdamson C, Burt SE et al. Developing a pooled job physical exposure data set from multiple independent studies: an example of a consortium study of carpal tunnel syndrome. Occup Environ Med 2015 Feb;72(2):130-7. https://doi. org/10.1136/oemed-2014-102396.
19. Harris-Adamson C, Eisen EA, Kapellusch J, Garg A, Hegmann KT, Thiese MS et al. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of2474 workers. Occup Environ Med 2015 Jan;72(1):33-41. https://doi. org/10.1136/oemed-2014-102378.
20. Borg G. Borg's perceived exertion and pain scales. Champaign, IL, US: Human Kinetics; 1998.
21. Latko WA, Armstrong TJ, Foulke JA, Herrin GD, Rabourn RA, Ulin SS. Development and evaluation of an observational method for assessing repetition in hand tasks. Am Ind Hyg Assoc J 1997 Apr;58(4):278-85. https://doi. org/10.1080/15428119791012793
22. American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values for Physical Agents. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists; 2001.
23. Schuhl P, editor. SiCore, The Insee Automatic Coding System. Bureau of the Census 1996 Annual Research Conference and Technology Interchange; 1996; Arlington, VA.
24. Falcon J. SocialPosition: Social Position Indicators Construction Toolbox. R package version 1.0.1. [software]. 2015. Available from: https://cran.r-project.org/ package=SocialPosition.
25. International standard classification of occupations: ISCO-08 structure, index correspondence with ISCO-88. International Labour Organization (ILO); c 2018 - [cited 2019 April 12]. Available from: www.ilo.org/public/english/bureau/stat/isco/ isco08
26. Lin DY, Wei LJ. The Robust Inference for the Cox Proportional Hazards Model. J Am Stat Assoc 1989;84:10748. https://doi.org/10.1080/01621459.1989.10478874.
27. Grant S, Chen YQ, May S. Performance of goodness-of-fit tests for the Cox proportional hazards model with timevarying covariates. Lifetime Data Anal 2014 Jul;20(3):35568. https://doi.org/10.1007/s10985-013-9277-1.
28. Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information-theoretic approach. 2 ed. New York, New York: Springer-Veflag; 2002.
29. Burnham KP, Anderson DR. Multimodel Inference: Understanding AIC and BIC in Model Selection. Sociol Methods Res 2004;33:261-304. https://doi. org/10.1177/0049124104268644.
30. Sauvé JF, Lavoué J, Nadon L, Lakhani R, Senhaji Rhazi M, Bourbonnais R et al. A hybrid expert approach for retrospective assessment of occupational exposures in a population-based case-control study of cancer. Environ Health 2019 Feb;18(1):14. https://doi.org/10.1186/s12940019-0451-0
31. Armstrong TJ, Buckle P, Fine LJ, Hagberg M, Jonsson B, Kilbom A et al. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand J Work Environ Health 1993 Apr;19(2):73-84. https://doi. org/10.5271/sjweh.1494.
Received for publication: 31 May 2019

DETAILS

Subject:	Population; Performance evaluation; Physical work; Models; Video recordings; Estimates; Regression analysis; Goodness of fit; Risk factors; Codes; Exposure; Overuse injuries; Risk analysis; Occupational exposure; Carpal tunnel syndrome; Variables; Statistical models; Job titles; Employment; Workers
Business indexing term:	Subject: Job titles Employment Workers
Location:	United States--US
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	248-258,248A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3855
ProQuest document ID:	2406985735
Document URL:	https://www.proquest.com/scholarly-journals/applying-two-general-population-job-exposure/docview/2406985735/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2022-04-26

What is precarious employment? A systematic review of definitions and operationalizations from quantitative and qualitative studies

Kreshpaj, B [1] ; Orellana, C; Burström, B; Davis, L; Hemmingsson, T; Johansson, G; Kjellberg, K; Jonsson, J; Wegman, D H; Bodin, T [1] Unit of Occupational Medicine, Institute of Environmental Medicine, Karolínska Institutet, Sweden

ABSTRACT (ENGLISH)

Objectives The lack of a common definition for precarious employment (PE) severely hampers the comparison of studies within and between countries, consequently reducing the applicability of research findings. We carried out a systematic review to summarize how PE has been conceptualized and implemented in research and identify the construct's dimensions in order to facilitate guidance on its operationalization.

Methods According to PRISMA guidelines, we searched Web of Science and Scopus for publications with variations of PE in the title or abstract. The search returned 1225 unique entries, which were screened for eligibility. Exclusion criteria were (i) language other than English, (ii) lack of a definition for PE, and (iii) non-original research. A total of 63 full-text articles were included and qualitative thematic-analysis was performed in order to identify dimensions of PE.

Results We identified several theory-based definitions of PE developed by previous researchers. Most definitions and operationalizations were either an accommodation to available data or the direct result of qualitative studies identifying themes of PE. The thematic-analysis of the selected articles resulted in a multidimensional construct including the following three dimensions: employment insecurity, income inadequacy, and lack of rights and protection.

Conclusions Despite a growing number of studies on PE, most fail to clearly define the concept, severely restricting the advancement of the research of PE as a social determinant of health. Our combined theoretical and empirical review suggests that a common multidimensional definition could be developed and deployed in different labor market contexts using a variety of methodological approaches.

FULL TEXT

Headnote

Objectives The lack of a common definition for precarious employment (PE) severely hampers the comparison of studies within and between countries, consequently reducing the applicability of research findings. We carried out a systematic review to summarize how PE has been conceptualized and implemented in research and identify the construct's dimensions in order to facilitate guidance on its operationalization.

Methods According to PRISMA guidelines, we searched Web of Science and Scopus for publications with variations of PE in the title or abstract. The search returned 1225 unique entries, which were screened for eligibility. Exclusion criteria were (i) language other than English, (ii) lack of a definition for PE, and (iii) non-original research. A total of 63 full-text articles were included and qualitative thematic-analysis was performed in order to identify dimensions of

PE.
Results We identified several theory-based definitions of PE developed by previous researchers. Most definitions and operationalizations were either an accommodation to available data or the direct result of qualitative studies identifying themes of PE. The thematic-analysis of the selected articles resulted in a multidimensional construct including the following three dimensions: employment insecurity, income inadequacy, and lack of rights and protection.
Conclusions Despite a growing number of studies on PE, most fail to clearly define the concept, severely restricting the advancement of the research of PE as a social determinant of health. Our combined theoretical and empirical review suggests that a common multidimensional definition could be developed and deployed in different labor market contexts using a variety of methodological approaches.
Key terms employment condition; epidemiology; occupational health; precariat; precarity.
Technological progress, shifts in economies, and an increased mobility of capital and workers over recent decades have transformed employment conditions (1, 2). Labor markets have witnessed a transition where new and more flexible forms of employment are replacing socalled "standard" forms of employment, generally associated with full-time, long-term, and secure jobs with entitlement to benefits (3, 4). While on the one hand, the increase in labor flexibility has been considered to have a positive impact on economic growth, on the other hand, it has contributed to a growth of atypical forms of employment of lower quality with potential adverse consequences, often referred to as precarious employment (PE) (5). PE is increasingly being recognized as a threat to health and well-being of workers and their families (3, 6) and is associated with mental and physical health (7, 8) as well as occupational injury risk (9). Mechanisms by which PE harms workers' health are largely unexplored (10, 11). Some researchers have developed multidimensional models and constructs of PE and examined the pathways and mechanism by which these are associated to health outcomes (6, 12-14).
Despite several attempts, there is no consensus on what constitutes PE and the various constructs or concepts used to describe it have greater or lesser currency depending on country and context (4). There is confusion when it comes to defining PE, as many related terms are used interchangeably: the precariat, precarious employment, precarious work, or simply precarity or precariousness. In the EU, the terms "atypical" or "nonstandard" forms of employment have been used extensively when referring to PE, while in the US the term "contingent work" is more common (4). The lack of a common definition severely hampers the comparison of studies and consequently reduces the applicability of research findings, despite high societal relevance. Leading researchers in the field have called for the development of a common definition based on objective measures (10, 15). PE is a term that has undergone substantial theoretical development and gained international traction over the last decades in many countries and research disciplines. There is a lively debate on how to define it, which is the rationale for limiting our work to PE specifically and deliberately excluding other concepts (16).
In order to support such an effort, we believe that a systematic review across disciplines of the available definitions of PE could lead to a better understanding of how PE is conceptualized and operationalized. Each research field approaches PE differently, therefore a classic Cochrane-style review is not appropriate. A synthesis and analysis of both qualitative and quantitative studies can promote a deeper understanding of this complex phenomenon, which will further advance for subsequent research on PE.
The aim of this study is to investigate how PE has been defined within research by reviewing the literature for definitions and operationalizations of PE and identify the construct's core dimensions in order to facilitate guidance on its operationalization.

Methods

Before conducting the review, a protocol was adapted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (17). During the process, guidance and standards were also followed from the Cochrane Handbook for Systematic Reviews of Interventions (18). The full protocol can be found as supplementary material A (www.sjweh.fi/ show_abstract.php?abstract_id=3875). This study is part of a larger project, with a published study protocol (19). Systematic review methods are well-developed when it comes to quantitative research studies, while methods for systematically reviewing a combination of both qualitative and quantitative research are still emerging and under development (20, 21). In this study, we have drawn on these methods also adding other qualitative methods to achieve our aims (see below).

Search strategy and eligibility criteria

The literature search was conducted in two multidisciplinary bibliographic databases: Web of Knowledge (all databases including the Web of Science Core Collection and MEDLINE) and Scopus.

We included any type of original publication (book, journal articles, conference proceedings etc.) of any type (observational, intervention, methodology, theory). Our exclusion criteria were (i) language other than English, (ii) lack of an explicit definition or operationalization of PE, and (iii) non-original research, such as systematic reviews or discussion papers. No restrictions were applied on year of publication, population or research discipline. We did not apply inclusion criteria related to quality of the publication. However, in the analysis, we considered the strength of both theoretical and empirical foundations of the different definitions and operationalizations. The search strategy was constructed using the same key words in both databases and by screening titles and abstracts. The key words were all related to or constructed from "precarious employment", using a spectrum of key words in order to allow a potentially broad inclusion of studies. In order to test the selected key words, pilot searches were conducted prior to the final search. The final search strings were the following:

WEB of Science: TI=(precari· AND (employ· OR job· OR work·)) OR TI=(precariat OR precarity)

Scopus: TITLE(precari· AND (employ· OR job· OR work·)) OR TITLE(precariat OR precarity)

Study selection and data collection

Figure 1 illustrates an overview of the selection process of the articles. The two database searches resulted in a total of 1850 records, which were downloaded to EndNote reference manager software. The software was then used to remove duplicates (N=816). Citations were thereafter uploaded to the online Covidence systematic review management software, which is the standard production platform for Cochrane reviews (Covidence systematic review software VHI, Melbourne, Australia). Firstly, this software was used to identify additional duplicates (N=8), leaving 1026 unique records to be assessed. Secondly, the first author screened titles and abstracts for relevance, and 437 studies were excluded because they did not match any of the inclusion criteria, leaving 589 hits to be screened in full-text for eligibility against the predefined exclusion criteria. Full-texts were retrieved through the online library resources. Authors and/or publishers were directly contacted if studies were unavailable through the library. Out of the 589 hits, 476 records were further excluded as not being an original or peer reviewed article (N=220), not stating a definition of PE (N=239) or not written in English (N=17).

Two reviewers assessed and extracted data from the remaining articles (N=113). If inclusion of an article was uncertain at this point, it was kept for the data extraction stage, which was conducted using an online google form developed by the authors, a method successfully used in previous reviews (8, 9). (Supplementary material B.) The form also allowed the reviewers to suggest the exclusion of an article and provide the reason for this. Article review and data extraction of each study was independently conducted by two of the nine reviewers. At this stage, an additional 50 records were excluded, leaving a total of 63 studies for the final analysis (12, 22-83). The main reason for exclusion at this stage was that articles had used PE as a theoretical framework for their study but did not properly define it in their research. In 35 studies, the reviewers had a disagreement with regard to inclusion/exclusion. The first and last authors re-examined and discussed jointly these articles until consensus was reached. All differences in the data extraction were resolved in the same way.

Data analysis

Quantitative and qualitative analyses were performed separately on the included articles in order to approach the complex multidimensional nature of PE.

Descriptive analysis

Descriptive data on study characteristics were extracted from the articles included in the review. These included: country of study, main outcome of the study, and the full definition of PE including separate extraction of each dimension in case the paper used a multi-dimensional definition. We used these data to present summary statistics for some important characteristics of the included studies. These were: region, research area, study design, primary outcome of the study (if any), type of PE definition, definition of PE created on an existing one, and number of dimensions of PE.

Qualitative analysis

A thematic-analysis approach - a widely used qualitative data analysis method focused on identifying patterned meanings across a data set (84) - was used to analyze the collected definitions and operationalizations, and consequently generate dimensions of PE. This approach involved three main steps with some overlap. In the first stage, after the descriptive analysis, a free line-by-line analysis of each PE definition and its dimension(s) was performed, and these were grouped into similar subthemes. Initially, these subthemes were kept as similar as possible to the meaning and wording of the original definition. In a second step, the subthemes were then examined and broader patterns of meaning were identified, and the subthemes grouped into aggregated themes with short descriptive labels, sought to describe each theme in one or a few words. Finally, several rounds of discussions were held among the authors to reach consensus on which subtheme should be designated to which theme and how these themes should be clustered into what we will henceforth call dimensions of PE. Inclusion or exclusion of the dimensions was then guided and based on a theoretical framework for PE developed by Bodin et al (16).

Theoretical framework

We anticipated that our thematic approach could generate dimensions that would fall outside the common understanding of PE and decided, a priori, to apply a theoretical framework to guide our analysis in the exclusion of such dimensions. The aim of the framework is to understand PE as a multidimensional construct where unfavorable features of employment quality accumulate in the same job (16). This framework builds on previous work by several leading researchers in this field (6, 12, 13, 85-87), and locates PE at the level of employment relationships to include salary, working times, contractual relationship and rights. Employment relationships, especially rights, are usually defined by laws, regulations and collective agreements. Social support through family and welfare systems are factors that very well might influence both the bargaining position of the workers as well as feelings of (in)security. As such, we believe that social support and the welfare state could be best seen as contextual or modifying factors. It also follows from our theoretical framework that boring, unsatisfying (88) low-status or hazardous work (89) should be seen as possible consequences of PE but not a defining characteristic. The same holds for health outcomes and job insecurity as a psychological (cognitive and/or affective) phenomenon as well as social precarisation (poverty, etc). This theoretical framework thus includes neither health consequences of work nor the related social or psychosocial concepts that might relate to quality of work. Both employer and employee are seen in broad terms, as these roles can take on a variety of legal and organizational forms in the ever-changing economic environment of gig and platform work, outsourcing and consulting.

Results

Descriptive analysis

Of the 63 research articles included in the review, the largest number were conducted in Europe (table 1). Canada (N=9) and South Korea (N=9) were the most common countries where studies were based. Other countries where >3 studies took place were Italy (N=6), Australia (N=6), and Spain (N=4). Several studies (N=7) were conducted in multiple countries. Research disciplines were defined a priori in the online google form developed by the authors and an option to add a discipline was given if the discipline was not listed. The most recurrent were respectively public, environmental or occupational health (N=29) followed by industrial relations (N=17), sociology (N=5), and economics (N=3). In all, 43 studies were quantita- tive observational studies (12, 22-63), while 18 were qualitative studies (64-81). Only one article conducted a mixed-methods approach (83) and one was an historical article (82). In 16 publications, definitions of PE were based on one or several pre-existing definitions in the literature (23, 32, 36, 42, 43, 58, 61-64, 69, 71, 72, 75, 78, 79). These included works by Amable (90), Benach et al (7), Burgess &Campbell (91), Kalleberg (92), Paugam (88), Piore (93), Rodgers (94), Standing (95, 96), Tompa et al (89), Tucker (97), Vives et al (12) and Vosko (98, 99). In the rest of the articles, the author(s) had either developed their own constructs based on theory, with no clear reference to previous work by others (although often inspired), or defined PE based on the availability of data either with or without reference to theory. When analyzing the number of dimensions used to define PE, 12 studies used only one dimension, 11 studies used two dimensions, while 40 were based on >3 dimensions.

Qualitative analysis

In total, our thematic-analysis resulted in five dimensions: (i) employment insecurity (ii) income inadequacy, (iii) lack of rights and protection, (iv) work environment, and (v) health effects and social consequences (table 2). Following the above-mentioned theoretical framework, we considered the definition of PE as dependent on characteristics of the employment relationship. Consequently, the two latter dimensions were excluded from consideration and were considered as possible consequences of PE but not as unique to or defining of such employment (supplementary material C). Thus, in the following sections we first focus on the three included dimensions of PE, derived from 145 extracted subthemes aggregated into ten themes (figure 2), followed by the excluded dimensions.

Included dimensions

Employment insecurity. In this first dimension, four major recurrent themes were identified: (i) contractual relationship insecurity, (ii) contractual temporariness, (iii) contractual underemployment, and (iv) multiple jobs/ sectors. Overall, 73 of the 145 subthemes, focused on different contractual aspects of PE in both qualitative and quantitative studies.

Contractual relationship insecurity was a predominant theme that emerged from the analysis. A person can be directly employed, employed through an agency or self-employed as well as being employed in other indirect ways depending on context. In the quantitative studies, being employed through an agency or being self-employed was usually contrasted to being directly employed (23, 27, 28, 31, 34, 49, 51, 57). From the analysis of the qualitative definitions, it was possible to capture the negative connotations associated with some of these subthemes, although no explicit comparison was made. For instance, being employed through an agency was described as the only choice available and was related to personal negative experiences (67, 82).

The studies investigating contractual temporariness focused on whether the person was employed on a fixed term contract or a permanent contract (25, 26, 29, 30, 39, 40, 47, 48, 52, 53, 56, 57, 82, 100). There was substantial heterogeneity in how these two concepts were defined. Within fixed term contracts, some studies included "on demand" contracts as well as seasonal employment (22, 32, 33, 100). Other times fixed-term contracts were identified by contract duration, with inconsistency as to length, ranging from longer than a month but shorter than a year, to contracts lasting<3 months or only a month (12, 36, 39, 61, 62). Insecurity deriving from fixed-term contracts and not knowing if, for how long or when these contracts were going to be renewed, was the major feeling experienced by the workers and described in the qualitative studies (67, 70, 73, 74, 81). Another way to consider the meaning of a fixed-term contract is to contrast it with the existence of stable job relationship between employer and employee. Giraudo et al (30) distinguished between number of working contracts and number of jobs held by a person in order to capture frequency of job changes, for instance if a first apprenticeship contract was followed by a permanent contract.

Contractual underemployment is represented by part-time versus full-time contracts. In some studies, parttime contracts were operationalized as having a contract guaranteeing<34 or 35 hours per week (39, 53). One study further specified part-time as working<35 hours/ week with a contract lasting >1 month (39). An aspect emerging from the analysis of these subthemes was involuntary part-time working, where part-time employees explicitly indicated that they were unable to find full-time work, therefore they would accept a part-time position (32, 33, 45, 46). Contractual underemployment does not include skill underemployment.

The subtheme multiple jobs/sectors was operationalized differently across studies but was described as either holding >1 contract or job or >1 job in different economic sectors (30, 32, 33, 46). None of the studies specified if these jobs or contracts were held simultaneously or for instance accounted for the total number of jobs held by a person within a year. One study operationalized this variable as any person holding a second job (46), while another further investigated the number of economic sectors in which a person was working and identified precarious workers in three different groups: those who on average work in three, four and more than four different jobs in two different economic sectors (30).

Income inadequacy. Even though this dimension encompasses only one theme - income level - there is a high heterogeneity in how studies have defined and operationalized this variable. Income level was mainly investigated as hourly wage, monthly salary, or annual income (12, 27, 36, 43, 59-62). One study made a distinction between direct and indirect income in order to be able to differentiate between wage and any supplementary income derived from other sources, such as government transfers and government- and employer-sponsored benefits (75). In all studies, to characterize income inadequacy, a low income level was set depending on the specific context and country, usually relating to national standards for minimum wage, poverty line or median income (44, 54, 58, 59, 78). Qualitative studies described the high feeling of uncertainty and insecurity deriving from a low income, as well as its inadequacy to provide stability (65, 83). They further highlighted physical and mental health effects, as well as poor living conditions related to a low and unstable salary (70, 77). Although "income volatility" was not derived as an explicit theme during the thematic analysis, the included articles highlighted unstable and inconsistent income as related to PE (65, 78).

Lack of rights and protection. Four main themes were related to this dimension: (i) lack of unionization, (ii) lack of social security, (iii) lack of regulatory support, and (iv) lack of workplace rights. These themes emerged in 26 articles with high heterogeneity among definitions and operationalizations in subthemes and, mainly due to diverse socio-economic and legislative contexts across countries.

Lack of unionization was primarily investigated as the existence of trade unions in the specific country under investigation and/or if the employees were in fact covered by a union (27, 58-60). An important feature emerging here is how workers' representation has declined over the years and how, in contrast, unionized workers have less risk of arbitrary dismissal compared to not unionized workers (27, 69).

When it comes to lack of social security, articles often did not specify how they accounted for and distinguish between in-work (employment) benefits and government determined social security benefits (53, 60, 71).

Two studies further distinguished between whether participants received medical insurance and social insurance (44, 60). This goes hand in hand with lack of regulatory support for full benefits, where the effectiveness of labor policies and labor standards were questioned (64, 69, 76, 82). Studies also investigated whether workers had access and/or power to exercise workplace rights such as, protection against unfair dismissal, protection from authoritarian treatment, discrimination or harassment (12, 36, 60, 78, 83). Other studies mainly looked at the effect of lack of workplace rights, from unacceptable working practices, forced labor and inability to demand better working conditions (12, 36, 61, 62, 66, 81).

Excluded dimensions

Work environment. This dimension consisted predominantly of themes and subthemes concerning psychosocial work environment such as lack of work-time control (schedule unpredictability) (53, 58, 66, 68, 70, 80), high work demands (long working hours) (42, 43, 46, 53, 66), skill discretion (being able to use and develop one's skills) (42, 45, 46, 53, 60, 65, 68, 72), as well as hazardous physical work environment (58, 60).

Health and social consequences. In this dimension, diverse themes were collected with the common features that they fall outside the realm of employment and work. The two most dominant themes in this dimension were health outcomes and social deprivation (46, 53, 62, 65, 70, 77). Social support was also a theme derived from a small number of studies (62, 67, 77).

Discussion

This systematic review shows how PE was defined across 63 studies from four different continents. Three overarching dimensions of PE emerged from the thematic-analysis: employment insecurity, income inadequacy, and lack of rights and protection. These three dimensions should not be interpreted as an attempt to launch yet another multi-dimensional definition of PE but rather as an organized summary of previous and present definitions and operationalizations. From the large number of screened studies, it is evident that researchers usually do not define or operationalize PE, despite being a term without a commonly accepted definition. The most common research discipline included in this review was Public or Occupational Health, where clear definitions of PE as an exposure are needed in order to design etiological studies of PE's effects on health. On the contrary, the full list of retrieved publications before screening was dominated by labor market studies, sociology and economics. Furthermore, even though most researchers today acknowledge PE as a multidimensional concept, most of the academic and public studies still apply unidimensional definitions or operationalizations, focusing predominantly on income level or employment status where long-term or full-time contracts are considered as non-PE.

Elements for a multidimensional concept of PE have appeared in the literature. Rodgers &Rodgers definition from 1989 underlined the importance that employment instability and insecurity play in PE (94). This is very similar to the derived dimension "employment insecurity", emerged from the reviewed studies that highlighted how contractual employment arrangements evoked feelings of insecurity and instability directed towards the future (67, 70, 73, 74, 81). Many studies looked at contract status as the only indicator for PE (25, 26, 31, 34, 37, 38, 41, 47, 48, 51, 52). We concur on the importance of contract status but suggest that focus should be put on duration of the contract into the future from the time-point it is measured, rather than looking at tenure. When considering multiple jobs/sectors, we further propose that questions measuring contract renewal unpredictability could be developed to account for those on recurrent fixed-term contracts.

The second dimension derived from the analysis - income inadequacy - reflected salaried work, a dimension which has been included with little variation in all theory-based definitions of PE we have come across (12, 27, 36, 44, 54, 58-62, 65, 75, 78). There is however, a debate as to whether income inadequacy should be measured solely on the individual's salaried work and benefits or should also account for either employment-related income protection such as sickness or unemployment benefits and/or household income (54, 65, 75, 101, 102). None of the studies in this review considered income from work-related benefits or insurance (sickness absence, unemployment etc.). Household income however is not determined by the employment relationship and should in our opinion be seen as a social protection scheme with variable importance depending on the context. A second aspect we believe relevant in this dimension, which derived from discussion among the co-authors and not from the reviewed studies, is income volatility. Two qualitative articles included in this review showed the high extent to which having an unstable and inconsistent income when precariously employed, affects someone's life (58, 65). The coherence of income volatility suggests the need to consider how volatile an individual's income is across months and years. Volatility could be very significant when estimating how stable or unstable employment is, and this can be further enhanced by looking at the direction of this volatility (income gain or loss) (103, 104). Studies not included in the review have shown how income volatility may be linked to an increase in job displacement and that it can reflect both unemployment/re-employment transitions, as for instance being in and out of involuntary part-time work (105, 106). While many studies have linked low income and adverse employment change to poor physical or mental health outcomes, income volatility and its public health consequences are yet to be explored (107, 108).

The last identified dimension, lack of rights and protection, is present in many PE definitions that aimed to investigate degrees of employment insecurity, employment quality and precariousness (27, 94, 95, 98). At the end of the 1990s and beginning of the 2000s, PE started to be characterized both as the relationship to instable and flexible employment conditions and by working conditions, such as having a badly paid job or lack of workers 'rights (109, 110). The key role and implications of union coverage, lack of social benefits, as well as general employment conditions experienced by the worker have been thoroughly investigated by a variety of authors (91, 94, 111, 112). This dimension is highly dependent on the context, which makes it difficult to operationalize in a way that works for researchers in different countries. A clear distinction should be made between individuals receiving social security based on their employment condition and those who receive it with no regard to their employment status. The qualitative studies included here highlight the need for PE workers to receive protection against unfair and authoritarian treatment - such as unjustifiable dismissal, discrimination, sexual harassment, and unacceptable working practices - the feeling of powerlessness to exercise their workplace rights, and mistrust towards the government for not providing support and transparency (36, 65, 69, 71, 78, 81). Rights and protection comprise an especially complicated dimension when studying informal or migrant work. This aspect needs more attention, particularly when considering that in 19 of 23 European countries under analysis, union membership among migrants was lower than among nationals (113).

Strength and limitations

PRISMA guidelines were followed to the extent possible and a research protocol was developed prior to conducting this systematic review. Even though integrating different types of studies and data within the same review remains challenging, we believe that qualitative research can and should be included in systematic reviews. To do so requires, however, that studies included in systematic reviews are of high quality and reliable and that all relevant research is included and conclusions are evidence-based (114, 115). On the other hand, a limitation is that there is yet little guidance when combining different study types in reviews. Studies written in lan- guages other than English and studies using synonyms or other terminology rather than PE were excluded from this review, which risks missing definitions of PE from some arenas. Nonetheless, the included studies were obtained from many different labor market contexts. The thematic-analysis performed on the data and the generation of subthemes and themes is a process of moving from the text under analysis to a higher level of conceptual abstraction.

This implies that the process is very dependent on the authors, which could be a potential limitation. In order to minimize subjective influence as much as possible, several rounds of analysis were conducted among our research group which includes researchers from several different disciplines and countries.

Implications

The debate on PE has become increasingly interdisciplinary and international and varies according to different labor markets, economies, and social systems. There is need for a common understanding of PE in order to understand its role as a social determinant of health. Based on this review, we believe that a common definition is both feasible, attainable, and likely to be useful in several contexts and research methodologies. National political and social contexts do matter when it comes to how and to what extent PE can affect individuals, and this needs to be taken into account. Unconsidered and unchecked, PE could lead to a dynamic transformation of the society as a whole. It is fundamental and important to grasp all its nuances in order to identify groups that are excluded from or find themselves in limbo with respect to being in the labor market. For the foreseeable future, PE is likely to be a permanent feature of our labor market, especially given rapid technological development and its consequences, thus a joint effort across disciplines and countries should be taken in order to keep worker's health as our main goal.

Concluding remarks

This systematic review did not aspire to present yet another multidimensional definition of PE, rather it summarizes the definitions previously and presently in use. Despite some differences in definitions and operationalizations across researchers, disciplines and countries, the results of this review show that a common definition of PE is likely attainable.

Funding

This review was supported by a grant from The Swedish Research Council for Health, Working Life and Welfare (FORTE) [grant number 2015-00933 and 2016-00315].

Sidebar

No recent systematic review has examined definitions of precarious employment in the literature. This review showed how precarious employment was defined across 63 studies from different continents and research disciplines. Three dimensions of precarious employment emerged: employment insecurity, income inadequacy, and lack of rights and protection.

Refers to the following texts of the Journal: 2015;41(4):329-337 2019;45(5):429-443 2018;44(4):341-350 2020;46(3):321-329 2014;40(5):465-472 2002;28(3):191-196

Key terms: definition; employment condition; epidemiology; occupational health; occupational health; precariat; precarious employment; precarity; review; systematic review

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31901944

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Kreshpaj B, Orellana C, Burström B, Davis L, Hemmingsson T, Johansson G, Kjellberg K, Jonsson J, Wegman DH, Bodin T. What is precarious employment? A systematic review of definitions and operationalizations from quantitative and qualitative studies. Scand J Work Environ Health. 2020;46(3):235-247. doi:10.5271/sjweh.3875
Correspondence to: Bertina Kreshpaj, MPH, Unit of Occupational Medicine, Institute of Environmental Medicine, Karolinska Institutet, Sweden. [E-mail: bertina.kreshpaj@ki.se]

Footnote

1 Unit of Occupational Medicine, Institute of Environmental Medicine, Karolinska Institutet, Sweden
2 Centre for Occupational and Environmental Medicine, Stockholm County Council, Stockholm, Sweden
3 Department of Public Health Sciences, Equity and Health Policy Research Group, Karolinska Institutet, Stockholm, Sweden
4 Occupational Health Surveillance Program, Massachusetts Department of Public Health, Boston, USA.
5 Department of Public Health Sciences, Stockholm University, Sweden
6 Department of Public Health, College of Health Sciences, University of Massachusetts Lowell, Lowell, USA

References

References

1. Benach J, Vives A, Tarafa G, Delclos C, Muntaner C. What should we know about precarious employment and health in 2025? Framing the agenda for the next decade of research. Int J Epidemiol 2016 Feb;45(1):232-8. https://doi. org/10.1093/ije/dyv342.
2. Kalleberg AL. Job quality and precarious work: clarifications, controversies, and challenges.(precarious work in polarizing times: a symposium on Arne L. Kalleberg's Good Jobs, Bad Jobs)(Good Jobs, Bad Jobs: The Rise of Polarized and Precarious Employment Systems in the United States, 1970s to 2000s)(Author abstract). Work Occup 2012;39(4):42748. https://doi.org/10.1177/0730888412460533.
3. Bosch G. Towards a New Standard Employment Relationship in Western Europe. Br J Ind Relat 2004;42(4):617-36. https://doi.org/10.1111/j.1467-8543.2004.00333.x.
4. Quinlan M. The 'pre-invention' of precarious employment: the changing world of work in context.(Report). Econ Labour Relat Rev 2012;23(4):3. https://doi. org/10.1177/103530461202300402.
5. OECD. The OECD Jobs Strategy: Progress Report on Implementation of Country-Specific Recommendations. 196. DWPN, editor1998.
6. Julia M, Vanroelen C, Bosmans K, Van Aerden K, Benach J. Precarious Employment and Quality of Employment in Relation to Health and Well-being in Europe. Int J Health Serv 2017 Jul;47(3):389-409. https://doi. org/10.1177/0020731417707491.
7. Benach J, Vives A, Amable M, Vanroelen C, Tarafa G, Muntaner C. Precarious employment: understanding an emerging social determinant of health. Annu Rev Public Health 2014;35:229-53. https://doi.org/10.1146/annurevpublhealth-032013-182500.
8. Rönnblad T, Grönholm E, Jonsson J, Koranyi I, Orellana C, Kreshpaj B et al. Precarious employment and mental health: a systematic review and meta-analysis of longitudinal studies. Scand J Work Environ Health 2019 Sep;45(5):42943. https://doi.org/10.5271/sjweh.3797.
9. Koranyi I, Jonsson J, Rönnblad T, Stockfelt L, Bodin T. Precarious employment and occupational accidents and injuries - a systematic review. Scand J Work Environ Health 2018 Jul;44(4):341-50. https://doi.org/10.5271/sjweh.3720.
10. Benach J, Vives A, Tarafa G, Delclos C, Muntaner C. What should we know about precarious employment and health in 2025? Framing the agenda for the next decade of research. Int J Epidemiol 2016 Feb;45(1):232-8. https://doi. org/10.1093/ije/dyv342.
11. Muntaner C, Solar O, Vanroelen C, Martínez JM, Vergara M, Santana V et al.; EMCONET Network. Unemployment, informal work, precarious employment, child labor, slavery, and health inequalities: pathways and mechanisms. Int J Health Serv 2010;40(2):281-95. https://doi.org/10.2190/ HS.40.2.h.
12. Vives A, Amable M, Ferrer M, Moneada S, Llorens C, Muntaner C et al. The Employment Precariousness Scale

(EPRES): psychometric properties of a new tool for epidemiological studies among waged and salaried workers. Occup Environ Med 2010 Aug;67(8):548-55. https://doi. org/10.1136/oem.2009.048967.
13. Vosko LF. Precarious employment: Understanding labour market insecurity in Canada. McGill-Queen's University Press Quebec; 2006.
14. Standing G. The precariat: The new dangerous class. London: Bloomsbury Publishing; 2016.
15. Benach J, Muntaner C, Benavides FG, Amable M, Jodar P. A new occupational health agenda for a new work environment. Scand J Work Environ Health 2002 Jun;28(3):191-6. https://doi.org/10.5271/sjweh.664.
16. Bodin T ÇC, Garde AH, Gnesi M, Jonsson J, Kiran S, Kreshpaj B, Leinonen T, Mehlum IS, Nena E, Orellana C, Peckham T, Seixas N, Vanroelen C, Julia M. Precarious employment in occupational health - an OMEGA-NET working group position paper. Scand J Work Environ Health 2019. Epub ahead of print. https://doi.org/10.5271/sjweh.3860.
17. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009 Jul;339:b2700. https://doi. org/10.1136/bmj.b2700.
18. Higgins J, Green S. Cochrane handbook for systematic reviews of interventions version 5.1.0 2011 [updated March 2011]. Available from: www.cochrane-handbook.org.
19. Orellana C, Kreshpaj B, Johansson G, Burström B, Kjellberg K, Hemmingsson T et al. Precarious employment, business performance and occupational injuries: a study protocol of a register-based Swedish project. BMJ Open 2019 Feb;9(2):e026091. https://doi.org/10.1136/ bmjopen-2018-026091.
20. Dixon-Woods M, Bonas S, Booth A, Jones DR, Miller T, Sutton AJ et al. How can systematic reviews incorporate qualitative research? A critical perspective. Qual Res 2006;6(1):27-44. https://doi. org/10.1177/1468794106058867.
21. Thorne S, Jensen L, Kearney MH, Noblit G, Sandelowski M. Qualitative metasynthesis: reflections on methodological orientation and ideological agenda. Qual Health Res 2004 Dec;14(10):1342-65. https://doi. org/10.1177/1049732304269888.
22. Beer A, Bentley R, Baker E, Mason K, Mallett S, Kavanagh A et al. Neoliberalism, economic restructuring and policy change: precarious housing and precarious employment in Australia. Urban Stud 2016;53(8):1542-58. https://doi. org/10.1177/0042098015596922.
23. Branch EH, Hanley C. A racial-gender lens on precarious nonstandard employment. Research in the Sociology of Work 2017;31:183-213. https://doi.org/10.1108/S0277283320170000031006.
24. Canivet C, Bodin T, Emmelin M, Toivanen S, Moghaddassi M, Östergren PO. Precarious employment is a risk factor for poor mental health in young individuals in Sweden: a cohort study with multiple follow-ups. BMC Public Health 2016 Aug;16:687. https://doi.org/10.1186/s12889-016-3358-5.
25. Ciairano S, Rabaglietti E, Roggero A, Callari T. Life Satisfaction, Sense of Coherence and Job Precariousness in Italian Young Adults. J Adult Dev 2010;17(3):177-89. https://doi.org/10.1007/s10804-010-9099-2.
26. Corbetta P, Colloca P. Job Precariousness and Political Orientations: the Case of Italy. South Eur Soc Polit 2013;18(3):333-54. https://doi.org/10.1080/13608746.201 3.769791.
27. Cranford CJ, Vosko LF, Zukewich N. The Gender of Precarious Employment in Canada. Relations Industrielles. 2003;58(3). https://doi.org/10.7202/007495ar.
28. David H, Cloutier E, Ledoux E. Precariousness, work organisation and occupational health: the case of nurses providing home care services in Quebec. Policy and Practice in Health and Safety. 2011;9(2):27-46. https://doi.org/10.10 80/14774003.2011.11667760.
29. Ek E, Sirviö A, Koiranen M, Taanila A. Psychological WellBeing. Job Strain and Education Among Young Finnish Precarious Employees. Soc Indic Res. 2014;115(3): 1057-69.
30. Giraudo M, Bena A, Leombruni R, Costa G. Occupational injuries in times of labour market flexibility: the different stories of employment-secure and precarious workers. BMC Public Health 2016 Feb;16(149):150. https://doi. org/10.1186/s12889-016-2834-2.
31. Han KM, Chang J, Won E, Lee MS, Ham BJ. Precarious employment associated with depressive symptoms and

suicidal ideation in adult wage workers. J Affect Disord 2017 Aug;218:201-9.
https://doi.org/10.1016/jjad.2017.04.049.
32. Hira-Friesen P. The effect of labour market characteristics on Canadian immigrant employment in precarious work, 2006-2012. Can J Urban Res 2017;26(1):1-15.
33. Hira-Friesen P. Immigrants and Precarious Work in Canada: Trends, 2006-2012. J Int Migr Integr 2018;19(1):35-57. https://doi.org/10.1007/s12134-017-0518-0.
34. Inoue M, Tsurugano S, Nishikitani M, Yano E. Full-time workers with precarious employment face lower protection for receiving annual health check-ups. Am J Ind Med 2012 Oct;55(10):884-92.
https://doi.org/10.1002/ajim.22090.
35. Jang SY, Jang SI, Bae HC, Shin J, Park EC. Precarious employment and new-onset severe depressive symptoms: a population-based prospective study in South Korea. Scand J Work Environ Health 2015 Jul;41(4):329-37. https://doi. org/10.5271/sjweh.3498.
36. Julia M, Vives A, Tarafa G, Benach J. Changing the way we understand precarious employment and health: precarisation affects the entire salaried population. Saf Sci 2017;100:6673.
https://doi.org/10.1016j.ssci.2017.01.015.
37. Kachi Y, Otsuka T, Kawada T. Precarious employment and the risk of serious psychological distress: a population-based cohort study in Japan. Scand J Work Environ Health 2014 Sep;40(5):465-72.
https://doi.org/10.5271/sjweh.3442.
38. Keuskamp D, Ziersch AM, Baum FE, Lamontagne AD. Precarious employment, psychosocial working conditions, and health: cross-sectional associations in a populationbased sample of working Australians. Am J Ind Med 2013 Aug;56(8):838-44. https://doi.org/10.1002/ajim.22176.
39. Kim IH, Khang YH, Muntaner C, Chun H, Cho SI. Gender, precarious work, and chronic diseases in South Korea. Am J Ind Med 2008 Oct;51(10):748-57. https://doi.org/10.m02/ ajim.20626.
40. Kim MH, Kim CY, Park JK, Kawachi I. Is precarious employment damaging to self-rated health? Results of propensity score matching methods, using longitudinal data in South Korea. Soc Sci Med 2008 Dec;67(12):1982-94.
https://doi.org/10.1016/j.socscimed.2008.09.051.
41. Kim W, Park EC, Lee TH, Kim TH. Effect of working hours and precarious employment on depressive symptoms in South Korean employees: a longitudinal study. Occup Environ Med 2016 Dec;73(12):816-22.
42. Kim Y. Changes in Precarious Employment Among South Korean Women. Math Popul Stud 2015;22(2):101-23.
https://doi.org/10.1080/08898480.2014.925354.
43. Kim Y. Precarious employment among South Korean women: insights from a comparison to France. Math Popul Stud 2018;25(1):41-61. https://doi.org/10.1080/08898480.2 017.1408356.
44. Kim YY, Baek SH, Lee SS. Precarious Elderly Workers in Post-Industrial South Korea. J Contemp Asia 2018;48(3):465-84. https://doi.org/10.1080/00472336.201 7.1423370.
45. Kretsos L, Livanos I. The extent and determinants of precarious employment in Europe. Int J Manpow 2016;37(1):25-43. https://doi.org/10.1108/IJM-12-20140243.
46. Livanos I, Nunez I. Early exit or longer stay? The effect of precarious employment on planned age of retirement. Person Rev 2017;46(8):1571-89. https://doi.org/10.1108/ PR-04-2015-0110.
47. Louie AM, Ostry AS, Quinlan M, Keegel T, Shoveller J, LaMontagne AD. Empirical study of employment arrangements and precariousness in Australia. Relations Industrielles. 2006;61(3). https://doi.org/10.7202/014186ar.
48. Milner A, LaMontagne AD, Spittal MJ, Pirkis J, Currier D. Job stressors and employment precarity as risks for thoughts about suicide: an australian study using the ten to men cohort. Ann Work Expo Health 2018 May;62(5):583-90. https://doi.org/10.1093/annweh/wxy024.
49. Min JY, Park SG, Hwang SH, Min KB. Disparities in precarious workers' health care access in South Korea. Am J Ind Med 2016 Dec;59(12):1136-44. https://doi.org/10.1002/ ajim.22658.
50. Min KB, Park SG, Hwang SH, Min JY. Precarious employment and the risk of suicidal ideation and suicide attempts. Prev Med 2015 Feb;71:72-6. https://doi. org/10.1016/j.ypmed.2014.12.017.

51. Modena F, Sabatini F. I would if I could: precarious employment and childbearing intentions in Italy. Rev Econ Househ 2012;10(1):77-97. https://doi.org/10.1007/s11150010-9117-y.
52. Moscone F, Tosetti E, Vittadini G. The impact of precarious employment on mental health: the case of Italy. Soc Sci Med 2016 Jun;158:86-95. https://doi.org/10.1016/j. socscimed.2016.03.008.
53. Oke A, Braithwaite P, Antai D. Sickness absence and precarious employment: A comparative cross-national study of Denmark, Finland, Sweden, and Norway. Int J Occup Environ Med 2016 Jul;7(3):125-47. https://doi. org/10.15171/ijoem.2016.713.
54. Olsthoorn M. Measuring Precarious Employment: A Proposal for Two Indicators of Precarious Employment Based on Set-Theory and Tested with Dutch Labor MarketData. Soc Indic Res 2014;119(1):421-41. https://doi. org/10.1007/s11205-013-0480-y.
55. Raymo JM, Warren JR, Sweeney MM, Hauser RM, Ho JH. Precarious employment, bad jobs, labor unions, and early retirement. J Geronyol B Psychol Sci Soc Sci. 2011 ;66B(2):249-59. https://doi.org/10.1093/geronb/ gbq106.
56. Robert P, Oross D, Szabo A. Youth, Precarious Employment and Political Participation in Hungary. Intersections-East Eur. J Society and Politics. 2017;3(1):120-46.
57. Rotenberg L, Griep RH, Fischer FM, Fonseca MJ, Landsbergis P. Working at night and work ability among nursing personnel: when precarious employment makes the difference. Int Arch Occup Environ Health 2009 Jul;82(7):877-85. https://doi.org/10.1007/s00420-0080383-4.
58. Scott-Marshall H, Tompa E. The health consequences of precarious employment experiences. Work 2011;38(4):36982. https://doi.org/10.3233/WOR-2011-1140.
59. Shuey KM, Jovic E. Disability Accommodation in Nonstandard and Precarious Employment Arrangements. Work Occup 2013;40(2):174-205. https://doi. org/10.1177/0730888413481030.
60. Sun Z, Chen J. Global city and precarious work of migrants in China: a survey of seven cities. Urban Geogr 2017;38(10):1479-96. https://doi.org/10.1080/02723638.2 017.1281056.
61. Vives A, Amable M, Ferrer M, Moncada S, Llorens C, Muntaner C, et al. Employment precariousness and poor mental health: Evidence from spain on a new social determinant of health. J Env Publ☺ic Health. 2013;1:978656.
62. Vives-Vergara A, González-López F, Solar O, BernalesBaksai P, González MJ, Benach J. Precarious employment in Chile: psychometric properties of the Chilean version of Employment Precariousness Scale in private sector workers. Cad Saude Publica 2017 Apr;33(3):e00156215. https://doi. org/10.1590/0102-311x00156215.
63. Vono de Vilhena D, Kosyakova Y, Kilpi-Jakonen E, McMullin P. Does adult education contribute to securing non-precarious employment? A cross-national comparison. Work Employ Soc 2016;30(1):97-117. https://doi. org/10.1177/0950017014561335.
64. Antonucci L. Not all experiences of precarious work lead to precarity: the case study of young people at university and their welfare mixes. J Youth Stud 2018;21(7):888-904. https://doi.org/10.1080/13676261.2017.1421749.
65. Ballafkih H, Zinsmeister J, Meerman M. A Job and a Sufficient Income Is Not Enough: The Needs of the Dutch Precariat. SAGE Open 2017;7(4). https://doi. org/10.1177/2158244017749069.
66. Bohle P, Quinlan M, Kennedy D, Williamson A. Working hours, work-life conflict and health in precarious and "permanent" employment. Rev Saude Publica 2004 Dec;38 Suppl:19-25. https://doi.org/10.1590/S003489102004000700004.
67. Bosmans K, Hardonk S, De Cuyper N, Vanroelen C. Explaining the relation between precarious employment and mental well-being. A qualitative study among temporary agency workers. Work 2015;53(2):249-64. https://doi. org/10.3233/WOR-152136.
68. Bozzon R, Murgia A, Poggio B, Rapetti E. Work-life interferences in the early stages of academic careers: the case of precarious researchers in Italy. Eur Educ Res J 2017;16(23):332-51. https://doi.org/10.1177/1474904116669364.
69. Burchielli R, Delaney A, Goren N. Garment homework in Argentina: drawing together the threads of informal and precarious work. Econ Labour Relat Rev 2014;25(1):63-80. https://doi.org/10.1177/1035304613518476.

70. Cañada E. Too precarious to be inclusive? Hotel maid employment in Spain. Tour Geogr 2018;20(4):653-74. https://doi.org/10.1080/14616688.2018.1437765.
71. Çelik C, Erkus-Öztürk H. Role of precariousness and space on class formation process: the case of Antalya's tourism workers. Cap Class 2016;40(3):419-45. https://doi. org/10.1177/0309816816653879.
72. Chan S, Tweedie D. Precarious Work and Reproductive Insecurity. Soc Alternatives 2015;34(4):5-13.
73. Costa HA, Costa ES. Precariousness and call centre work: Operators' perceptions in Portugal and Brazil. Eur J Ind Relat 2018;24(3):243-59. https://doi. org/10.1177/0959680117736626.
74. Cunningham I, Baines D, Shields J, Lewchuk W. Austerity policies, 'precarity' and the nonprofit workforce: A comparative study of UK and Canada. J Ind Relat 2016;58(4):455-72. https://doi. org/10.1177/0022185616639309.
75. Daly T, Armstrong P. Liminal and invisible longterm care labour: precarity in the face of austerity. J Ind Relat 2016 Sep;58(4):472-90. https://doi. org/10.1177/0022185616643496.
76. D'Amours M. Non-standard employment after age 50: how precarious is it? Relat Ind 2009;64(2):209-29. https://doi. org/10.7202/037918ar.
77. Dileep Kumar M, Ismail NA, Govindarajo NS. Way to measure the concept precarious working conditions in oil palm plantations. Asian Soc Sci 2014;10(21):99-108.
78. Hannif Z, Lamm F. When Non-Standard Work Becomes Precarious: Insights from the New Zealand Call Centre Industry. Manage Rev 2005;16(3):324-50.
79. Jokela M. The Role of Domestic Employment Policies in Shaping Precarious Work. Soc Policy Adm 2017;51(2):286307. https://doi.org/10.1111/spol.12288.
80. Premji S. "It's Totally Destroyed Our Life": Exploring the Pathways and Mechanisms Between Precarious Employment and Health and Well-being Among Immigrant Men and Women in Toronto. Int J Health Serv 2018 Jan;48(1):10627. https://doi.org/10.1177/0020731417730011.
81. Swider S. Building China: precarious employment among migrant construction workers. Work Employ Soc. 201 5 ;29(1) :41 -59. https://doi. org/10.1177/0950017014526631.
82. Black S. Mitigating precarious employment in New York City's home-based child care sector. Labour Cap Soc 2012;45(1):96-121.
83. Cam S, Palaz S. Demarcation of the core and periphery dichotomy: evidence from Turkey's shipyards for a paradoxical precarity model. Ind Relat J 2018;49(2):153-73. https://doi.org/10.1111/irj.12208.
84. Boyatzis RE. Transforming qualitative information: thematic analysis and code development. London, Thousand Oaks, CA. 1998.
85. Rodgers G, Rodgers J. Precarious jobs in labour market regulation: The growth of atypical employment in Western Europe: ILO; 1989.
86. Quinlan M, Mayhew C, Bohle P. The global expansion of precarious employment, work disorganization, and consequences for occupational health: a review of recent research. Int J Health Serv 2001;31(2):335-414. https://doi. org/10.2190/607H-TTV0-QCN6-YLT4.
87. Benach J, Vives A, Amable M, Vanroelen C, Tarafa G, Muntaner C. Precarious employment: understanding an emerging social determinant of health. Annu Rev Public Health 2014;35(1):229-53. https://doi.org/10.1146/annurevpublhealth-032013-182500.
88. Paugam S. Le salarié de la précarité. [The Precarious Worker.] Paris: Presses Universitaires de France, 2000.
89. Tompa E, Scott-Marshall H, Dolinschi R, Trevithick S, Bhattacharyya S. Precarious employment experiences and their health consequences: towards a theoretical framework. Work 2007;28(3):209-24.
90. Amable MB, González S. La precariedad laboral y su repercusión sobre la salud: conceptos y resultados preliminares de un estudio multimétodos. Arch Prev Riesgos Labor 2001;4:169-84.
91. Burgess J, Campbell I. The Nature and Dimensions of Precarious Employment in Australia. Labour &Industry: a journal of the social and economic relations of work. 1998;8(3):5-21.
92. Kalleberg AL, Reskin BF, Hudson K. Bad jobs in America: standard and nonstandard employment relations and job quality in the United States. Am Sociol Rev 2000;65:25678. https://doi.org/10.2307/2657440.

93. Piore ME. The Dual Labour Market: Theory and Implications. Winthrop Publishers. 1970.
94. Rodgers G, Rodgers J. Precarious Jobs in Labour Market Regulation: The Growth of a Typical Employment in Western Europe. In: Precarious employment in Western Europe: the state of the debate. Geneva: International Institute for Labour Studies (ILO). 1989; p. 1-15.
95. Standing G. Globalization, Labour Flexibility and Insecurity: The Era of Market Regulation. Eur J Ind Relat 1997;3(1):7-37. https://doi.org/rn.n77/095968019731002.
96. Standing G. Global Labour Flexibility: Seeking Distributive Justice. St Martin's Press, New York, NY. 1999.
97. Tucker D. Precarious Non-Standard Employment - A review of literature. Labour Market Policy Group, Department of Labour: Wellington. 2002.
98. Introduction VL. In: Comparative Perspectives Database on Precarious Employment. 2015.
99. Kalleberg AL. Managing the Margins- Gender, Citizenship, and the International Regulation of Precarious Employment - By Leah F Vosko. Br J Ind Relat 2011;49(3):589-91. https://doi.org/10.1111/j.1467-8543.2010.00843_4.x.
100. Canivet C, Bodin T, Emmelin M, Toivanen S, Moghaddassi M, Östergren PO. Precarious employment is a risk factor for poor mental health in young individuals in Sweden: a cohort study with multiple follow-ups. BMC Public Health 2016 Aug;16(1):687. https://doi.org/10.1186/s12889-016-3358-5.
101. Mentzakis E, Moro M. The poor, the rich and the happy: exploring the link between income and subjective wellbeing. J. Socio-Econ. 2009;38(1):147-58. https://doi. org/10.1016/j.socec.2008.07.010.
102. Boes S, Winkelmann R. The Effect of Income on General Life Satisfaction and Dissatisfaction. Soc Indic Res 2010;95(1):111-28. https://doi.org/10.1007/s11205-0099452-7.
103. Farrell D, Greig, F. Paychecks, Paydays, and the Online Platform Economy: Big Data on Income Volatility JPMorgan Chase &Co Institute. 2016.
104. Flug K, Spilimbergo A, Wachtenheim E. Investment in education: do economic volatility and credit constraints matter? J Dev Econ 1998;55(2):465-81. https://doi. org/10.1016/S0304-3878(98)00045-5.
105. Prause J, Dooley D, Huh J. Income volatility and psychological depression. Am J Community Psychol 2009 Mar;43(1-2):57-70. https://doi.org/10.1007/s10464-0089219-3.
106. Stevens AH. Changes in Earnings Instability and Job Loss. Ind Labor Relat Rev 2001;55(1):60-78. https://doi. org/10.1177/001979390105500104.
107. Dooley D, Prause J. Mental health and welfare transitions: depression and alcohol abuse in AFDC women. Am J Community Psychol 2002 Dec;30(6):787-813. https://doi. org/10.1023/A:1020253002468.
108. Martikainen P, Adda J, Ferrie JE, Davey Smith G, Marmot M. Effects of income and wealth on GHQ depression and poor self rated health in white collar women and men in the Whitehall II study. J Epidemiol Community Health 2003 Sep;57(9):718-23. https://doi.org/10.1136/jech.57.9.718.
109. Gutiérrez-Barbarrusa T. The growth of precarious employment in Europe: Concepts, indicators and the effects of the global economic crisis. Int Labour Rev 2016;155(4):477-508. https://doi.org/10.1111/ilr.12049.
110. Paugam SR. The Effects of Employment Precarity and Unemployment on Social Isolation. In: Gallie D., Paugam S., eds., Welfare Regimes and the Experience of Unemployment in Europe. Oxford University Press. 2000:243-64.
111. Cranford C, Vosko L, Zukewich N. The Gender of Precarious Employment in Canada. 2003:58(3). https://doi. org/10.7202/007495ar.
112. Vosko LF. Temporary Work. The Gendered Rise of a Precarious Employment Relationship: University of Toronto Press; 2000.
113. Kranendonk M, Beer P. What Explains the Union Membership Gap between Migrants and Natives? Br J Ind Relat 2016;54(4):846-69. https://doi.org/10.1111/ bjir.12192.
114. Dixon-Woods M, Fitzpatrick R. Qualitative research in systematic reviews. Has established a place for itself. 2001;323(7316):765-6.
115. Harden A, Thomas J. Methodological Issues in Combining Diverse Study Types in Systematic Reviews. Int J

Soc Res Methodol 2005;8(3):257-71. https://doi. org/10.1080/13645570500155078.
Received for publication: 5 August 2019

DETAILS

Subject:	Research; Library collections; Qualitative analysis; Researchers; Citation management software; Empirical analysis; Bibliographic data bases; Studies; Reviews; Systematic review; Employment; Labor market
Business indexing term:	Subject: Employment Labor market
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	235-247,235A
Publication year:	2020
Publication date:	2020
Section:	Review
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Evidence Based Healthcare, Journal Article
DOI:	https://doi.org/10.5271/sjweh.3875
ProQuest document ID:	2406985404
Document URL:	https://www.proquest.com/scholarly-journals/what-is-precarious-employment-systematic-review/docview/2406985404/se-2?accountid=211160

Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2020-11-05
Database:	Public Health Database

Is the association between poor job control and common mental disorder explained by general perceptions of control? Findings from an Australian longitudinal cohort

Too, L S; Leach, L; Butterworth, P

ABSTRACT (ENGLISH)

Objectives This study sought to examine the influence of general perceptions of control on the association between job control and mental health. Methods We used four waves of data from a cohort of mid-aged adults from the Personality and Total Health (PATH) Through Life Study (baseline N=2106). Key measures included job control and likelihood of experiencing a common mental disorder (anxiety and/or depression). The data were analyzed using longitudinal randomintercept regression models, controlling for a range of potential confounders including general perceptions of control (ie, not isolated to the work context) via a measure of mastery. The analyses isolated the effect of withinperson changes in job control on mental health (apart from between-person differences). Results The results show that the effect of job control remained significant after adjusting for general perceptions of control and other confounders. The within-person effect in the model demonstrated that, when workers had low job control, they were twice as likely to experience a common mental disorder [odds ratio (OR) 2.04, 95% confidence interval (CI) 1.53-2.73]. Conclusions Individuals' general perceptions of control in life does not account for the association between low job control and poor mental health. The findings add a new layer of evidence to the literature demonstrating that lack of autonomy at work is an independent predictor of employees' mental health. Increasing employee control should be integrated into workplace strategies to promote mental health. Key terms Australia; depression; job stressor; mental health; psychosocial; stress.

FULL TEXT

Headnote

Objectives This study sought to examine the influence of general perceptions of control on the association between job control and mental health.

Methods We used four waves of data from a cohort of mid-aged adults from the Personality and Total Health (PATH) Through Life Study (baseline N=2106). Key measures included job control and likelihood of experiencing a common mental disorder (anxiety and/or depression). The data were analyzed using longitudinal randomintercept regression models, controlling for a range of potential confounders including general perceptions of control (ie, not isolated to the work context) via a measure of mastery. The analyses isolated the effect of withinperson changes in job control on mental health (apart from between-person differences).

Results The results show that the effect of job control remained significant after adjusting for general perceptions of control and other confounders. The within-person effect in the model demonstrated that, when workers had low job control, they were twice as likely to experience a common mental disorder [odds ratio (OR) 2.04, 95% confidence interval (CI) 1.53-2.73].

Conclusions Individuals' general perceptions of control in life does not account for the association between low job control and poor mental health. The findings add a new layer of evidence to the literature demonstrating that lack of autonomy at work is an independent predictor of employees' mental health. Increasing employee control should be integrated into workplace strategies to promote mental health.

Key terms Australia; depression; job stressor; mental health; psychosocial; stress.

Globally, mental illness is a key contributor to disability burden (1). In an effort to reduce the prevalence of mental illness, risk factor identification (and prevention) in the workplace has become a major focus of research as well as both government and employment policy (2). Systematic reviews and meta-analyses have consistently found that psychologically stressful employment conditions (including jobs with high demands, low control/autonomy, insecurity, and poor social support) are associated with poorer mental health (3-6). This research field is primarily influenced by Karasek's job demands-control model (7). The model posits that job strain, a state produced by the combination of high job demands and low job control, places employees at an increased risk of health problems. Following on from the job strain model, much of the literature investigating psychosocial job conditions and mental health has focused on combined (rather than single) indicators of psychosocial stress at work. For example, multiple longitudinal studies have shown that high job strain (high demands and low control) precedes declines in mental health (8-12) as do increases in the number of adverse psychosocial job conditions experienced (eg, combined experiences of high job demands, low job control, job insecurity) (13, 14).

Research has also examined the individual indicators of poor psychosocial job quality and, in the case of most indicators including low job control, has reliably shown an association with poorer mental health. For example, a UK study by Stansfeld et al (15) showed an increased risk of psychiatric disorders among those with low decision authority. Bentley et al (16) and Butterworth et al (17) analyzed seven or more waves of Australian panel data and showed that mental health improved with increases in job control over time. A recent UK longitudinal study by Harvey et al (12) found that low job control predicted higher odds of subsequent common mental disorder. While there is a substantial body of research linking low job control with poorer mental health, the possibility of residual confounding remains a major barrier to causal interpretations in longitudinal research (12). There are many non-work related mental health risk factors that may be associated with self-reported job control, including psychological resources and personality characteristics. While research by Stansfeld et al (15) and Harvey et al (12) did control for some aspects of personality (eg, adult hostility and adolescent temperament respectively), very little research has considered the role that perceptions of control more broadly (ie, not isolated to the work context) might play. Measures of control in the workplace may simply be a proxy for perceptions of control more generally, or alternatively, it may be that control in the workplace is associated with mental health independent of non-work influences. One relevant study by Clark et al (18) used cross-sectional data from the 2007 UK Adult Psychiatric Morbidity Survey to investigate the contribution of both work and non-work stressors to common mental disorders. The findings suggest that the effects of work stressors are not explained by broader non-work stressors such as adverse life events (eg, financial strain, separation/ divorce, domestic violence), caring responsibilities, and low social support. However, this research only used data from a single point in time and did not specifically investigate the contribution of control within and outside the workplace.

The current study aims to fill this knowledge gap by using four waves of Australian community-based data to examine the association between job control (one of the main components in Karasek's job demands-control model) and common mental disorder, independent of a broader sense of control in life. It is important to account for the influence of control more broadly, as without doing so, the effect of job control might simply reflect perceptions of low control over life circumstances more generally rather than being specific to work. This study separated within- and between-person differences in both job control and broader sense of control to show how time-varying change in job control is associated with change in mental health, adjusted for other residual confounders (eg, between-person differences in job control as well as within- and between-person broader sense of control). The findings are reported according to the STROBE statement for cohort studies (19).

Methods

Participants

Participants were from the Personality and Total Health (PATH) Through Life Project, a large longitudinal community survey on individual health and well-being trajectories across the life course. The survey was undertaken by the Centre for Research on Ageing, Health and Wellbeing at the Australian National University (ANU). The sample comprises cohorts of young, midlife, and older adults randomly selected from the Australian Electoral Rolls of Australian Capital Territory and the neighboring town of Queanbeyan (20). The current study was restricted to the midlife cohort who were aged 40-44 years at baseline, and subsequently assessed every (approximately) four years from 2000/2001 (wave 1) to 2012/2013 (wave 4). The participation rate of this cohort at baseline was 65% (2530 participants), where 93% of baseline participants completed the survey at wave 2, 86% at wave 3, and 71% at wave 4 (figure 1). For the first three waves, participants were typically assessed in their own home or at the ANU. They were invited to complete a questionnaire using a laptop computer under the supervision of a trained interviewer. For the fourth wave, participants were invited to complete an online version of the questionnaire and those in the local area were invited to undertake additional face-to-face assessment. All participants provided informed consent to participate at each wave of the study, and each wave of data collection was approved by the Human Research Ethics Committee of the Australian National University.

The current study excluded observations from participants when they (i) were not employed (ie, unemployed or not active in the labor force); (ii) were employed but on long-term leave; or (iii) did not provide information on their status of employment (figure 1). Given the longitudinal focus, participants with fewer than two waves of data were also excluded.

Measures

Common mental disorder. Anxiety and depression were assessed using the Goldberg Anxiety and Depression scales (21) at all four waves. Each scale comprises nine binary items (yes or no) about anxiety or depressive symptoms experienced in the past month. The total score for each measure was computed by summing the number of "yes" responses and dichotomized using the established cut-off points indicative of symptoms of anxiety or depressive disorders (22). A binary measure of common mental disorder was then generated based on the presence of depressive and/or anxiety symptoms. A continuous measure of common mental disorder severity was also calculated based on number of symptoms of anxiety and depression experienced (ranging from 0-18) - this measure was adopted in sensitivity analyses.

Control at work. At all four waves, 15 items from the Whitehall II study (23) assessed aspects of job control (eg, skill discretion: "Do you have a choice in deciding how you do your job?"; decision authority: "Does your job provide you with a variety of interesting things?"). These items offered four response categories: 1=often, 2=sometimes, 3=rarely, and 4=never. Aligned with the methodology used in previous studies (17, 24), a score for job control was calculated by combining the average scores for skill discretion and decision authority and then divided into tertiles identifying three groups representing high, medium, and low job control. This approach was similarly used in the Whitehall II study (15). In addition to the time-varying measure of job control, a between-person (ie, time-invariant) measure was computed to identify respondents who experienced low job control at some point over the four waves. This measure was used as indicator of individual susceptibility or vulnerability to experience adverse job conditions.

General perceptions of control

General perceptions of control assessed by the Pearlin Mastery Scale (25), which was included in all waves. Perceived mastery is a psychological resource that has been defined as "the extent to which one regards one's life-chances as being under one's own control in contrast to being fatalistically ruled" (25). The items (eg, "There is really no way I can solve some of the problems I have" and "I have little control over the things that happen to me.") offered four response categories: 1=strongly agree, 2=agree, 3=disagree, and 4=strongly disagree. The seven items were summed and the total score categorized into tertiles, representing high, medium, and low general control. The analyses also included a between-person (ie, time-invariant) measure of general control, derived by calculating respondents average mastery scale score over the survey waves.

Other covariates

Work-related. Four items from the Whitehall II study (23) assessing aspects of job demands (eg, "Do you have to work very intensively") with four response categories (1=often, 2=sometimes, 3=rarely, and 4=never) were included from all waves. As with job control, we computed the average score for this measure and then used tertiles to identify three groups representing high, medium, and low job demands. One item: "How secure do you feel about your job or career future in your current workplace?" with four response categories ("not at all secure", "moderately secure", "secure", "extremely secure") was used to assess job insecurity. The former two categories were coded as high insecurity and the latter two as low insecurity.

Sociodemographic and health covariates. We included other variables that may potentially confound the association between job control and common mental disorders (2628): time-invariant measures from baseline (ie, gender, educational attainment) and time-varying measures from each wave (ie, partner status, occupational skill level, parental responsibilities, childhood adversity, financial hardship, chronic physical health conditions, smoking status, alcohol consumption, and physical exercise).

Seventeen items on childhood adversity were adopted and adapted from the Parental Bonding Instrument (29), the British National Survey of Health and Development (30), the US National Comorbidity Survey (31), and from open-ended responses in a previous cross-sectional study (32). These items comprised six covering parental affection, parental nervous/emotional trouble, and parental drinking/drug problems; two covering conflict in the household and parental divorce/separation; eight covering neglect, authoritarian upbringing, witnessing physical/sexual abuse, as well as verbal abuse, psychological abuse, physical abuse, physical punishment, and sexual abuse by a parent; and one item covering childhood poverty/financial hardship. Participants were categorized as having childhood adversity if they responded yes to any of these items. Current financial hardship was generated based on one item: "Have you or your family had to go without things you really needed in the last year because you were short of money?" Respondents were classified as having financial hardship if they responded yes, often or yes, sometimes to this item.

Chronic physical health conditions including heart problems, hypertension, cancer, arthritis, thyroid problems, epilepsy, asthma, diabetes, and stroke were considered and coded as a summary variable representing the experience of 0, 1, or >2 of these conditions. Hazardous/ harmful alcohol consumption (33) was derived from the Alcohol Use Disorders Identification Test (34) and classified as yes and no. The hours respondents engaged in moderate or vigorous physical exercise per week was assessed by items in the Whitehall II study (35) and categorized into five groups: 0, <1.5, 1.5-3, 3.1-5.5, and >5.5 hours. The categories of covariates not described in detail above are presented in table 1.

Statistical analyses

Sample characteristics at baseline and descriptive information for job control and common mental disorder at each wave were reported. Chi-square test was used to assess the relationship between job control and general control. To appropriately model the lack of independence in the data, given repeated measures from the same individuals, longitudinal random-intercept logistic regression models with two levels (occasion clustered within individuals) were used to assess the association between job control and common mental disorder over time (36). These models also facilitate the use all available data (rather than restriction to complete case analysis), and permit the decomposition of time-varying covariates into elements representing within-person change over time and consistent between-person differences (36). The model fitted a fixed (average) regression slope for common mental disorder over time while permitting the intercept to vary between respondents to reflect differences between individuals in their likelihood of common mental disorder. The longitudinal models first included time-varying job control (model 1) and general control (model 2), followed by between-person terms for job control and general control (model 3), and finally other work-related covariates, sociodemographic, and health variables (model 4). Survey wave (a category term) was included in all models. We also assessed the association of each covariate with common mental disorder, adjusted for survey wave only.

In addition, we compared the model comprising only the main effects of job control and general control with a model that also incorporated the interaction term using the likelihood ratio test. We did the same test for job control and gender, and for general control and gender.

The proportion of observations with missing data on all variables was low, ranging from 0-1.5% (financial hardship was highest). All analyses were conducted using Stata Statistical Software: release 14 (StataCorp, College Station, TX, USA).

Sensitivity analyses

Sensitivity tests included repeating the analyses (using negative binomial regression models) with a continuous outcome representing severity of common mental disorder to assess whether the results from these models differed from those obtained from the models with binary outcome of common mental disorder. Another sensitivity test repeated the analyses with a fixed-effect model rather than a random-effect model with betweenperson terms.

Results

The study included 2106 participants aged 40-44 at baseline (table 1, see descriptions of sample character- istics by level of job control in table 1 and by level of general control in table S4 in the supplementary material, www.sjweh.fi/show_abstract.php?abstract_id=3869). Of these participants, half were male, 20% did not have a partner, 27% did not complete high school, 20% were in low-skilled occupations, 66% had a youngest child aged <15 years, 61% experienced >1 adversity during childhood, and 18% were experiencing financial hardship. In terms of their health, 10% of participants had >2 chronic physical health conditions, 18% currently smoked, 6% consumed alcohol at hazardous/harmful levels, and 19% spent less than an hour doing moderate/vigorous physical exercise per week.

The chi-square test showed a significant relationship between job control and general control [X2(4, N=2092) = 205.38, P<0.001]. However, 17% of respondents who reported low job control also reported high general control. Similarly, 17% who reported high job control also reported low general control, suggesting these two measures were not collinear.

There was movement between low, medium, and high categories of job control and general control over the 12-year period (table 2). The proportion of respondents reporting low job control at any point in time (55%) was greater than the proportion at each wave (eg, 35% at wave 4). The proportion of respondents reporting low general control at any point in time (40%) was also greater than the proportion at each wave (eg, 23% at wave 4). There was also variability over time in common mental disorder. Around 42% of respondents reported symptom levels reflective of a common mental disorder at some point over the survey waves.

Job control and common mental disorder over time

Table 3 shows a series of models investigating the association between job control and likelihood of common mental disorder. Job control was significantly associated with common mental disorder in simple and adjusted models, although the magnitude of the effect was attenuated after controlling for general control. After adjusting for all covariates, including between-person differences in job control and general control, the results show that when individuals were in jobs with low control (ie, within-person change) they were at twice the risk of common mental disorder compared to when they held a job with high control (OR 2.04, 95% CI 1.53-2.73). Other variables associated with greater risk of common mental disorder in the final model included current experiences of low general control (eg, within-person effect) and overall average perceptions of general control (eg, between-person effect), high job demands and job insecurity, being female, childhood adversity, financial hardship, having one or more chronic physical conditions, and smoking. Those who had a low skilled occupation appeared at lower risk (although this likely arose from over-adjustment in the final model given the opposite pattern was evident in the univariate analysis). In all models, there was a significant effect of time, suggesting that the odds of common mental disorders decreased after baseline. The interactions between job control and general control, between job control and gender, and between general control and gender were not significant.

Results from the sensitivity analyses

In sensitivity analyses we observed a similar pattern of results with the count outcome as when a binary outcome was adopted. A model adjusting for all covariates showed that low job control was significantly associated with greater severity of common mental disorder [incidence rate ratio (IRR) for low versus high job control was 1.19, 95% CI 1.13-1.25]. The same pattem of results was also found using a fixed-effect model (OR for low versus high job control was 2.23, 95% CI 1.59-3.13).

Discussion

The current study analyzed four waves of community cohort data to examine whether the association between control at work and risk of common mental disorder is independent of general perceptions of control. The findings show that after adjusting for the adverse effect of low perceptions of control generally, being in a job with low control was independently associated with a two-fold risk of common mental disorder. This effect remained after adjusting for between-person differences in (or susceptibility to) low control both within the workplace and more generally, job demands, job insecurity, and sociodemographic and health confounders.

The current study supports previous research indicating that low job control is an important independent predictor of poor mental health. This finding extends existing knowledge from a variety of countries, including Australia (where improvement in job control has been associated with better mental health (16), and in the UK (12, 15). More importantly, the current study makes a unique contribution by showing that the mental health impact of low job control is not simply a measurement artefact, or a subset or reflection of perceptions of low control over life circumstances more broadly. In addition, the separation of within- and between-subject effects in the present study furthers efforts to distinguish the impact of low job control from other residual confounders, including those within and outside the workplace. Together with intervention studies that have shown the mental health benefits of increasing employee control (37), our findings indicate that good job control should be a target for workplace policy and practice. The findings negate concerns that work-based change will be ineffective if broader issues within the personal lives of employees are not addressed.

There are some limitations that should be considered in the interpretation of our findings. First, the sample was recruited from Canberra and Queanbeyan, in Australia. As Canberra is a city that includes many professionals and public servants, (baseline sample comprised of 53% professionals), the results may not be replicated in samples drawn from more disadvantaged communities, nor the broader Australian population. Second, as the study only included data from the path midlife cohort (aged 40-44 at baseline), the findings may not be generalizable to other age cohorts. For example, in adolescents and young adults at the start of their working lives, norms of job control may be lower and have less impact on mental health. Finally, as the measures of job control, mastery, and mental health were self-reported, the data may be either underreported or overreported due to recall bias.

Concluding remarks

The current study adds to the evidence that low job control is a significant, independent risk factor for common mental disorder, independent of general perceptions of control and other individual differences. The findings underscore the importance of psychologically stressful employment conditions for mental health, and the benefits of considering the workplace as a context for protecting and promoting good mental health.

Acknowledgements

The authors thank the study participants, PATH Interviewers, Karen Maxwell and Trish Jacomb, and other PATH Chief Investigators: Kaarin Anstey, Helen Christensen, Anthony Jorm, Bryan Rodgers, Andrew Mackinnon, Simon Easteal and Nicolas Cherbuin.

Conflict of interests

Authors declare no conflicts of interest.

Funding

The PATH Through Life Study was funded by the National Health and Medical Research Council (973302, 179805, 418139), and the Australian Government Agency - Safe Work Australia. It is currently managed by both the ANU and the University of New South Wales. PB was supported by ARC Future Fellowship (FT130101444) and a

University of Melbourne Faculty of Medicine, Dentistry and Health Sciences Research Fellowship. The funders had no involvement in the (i) study design, (ii) the collection, analysis and interpretation of the data, (iii) the writing of the report, and (iv) the decision to submit the paper for publication.

Ethics approval

The Australian National University Human Research Ethics Committee approved the PATH Through Life Project: #M9807; #2002/190; #2006/314 and #2010/542.

Sidebar

After adjusting for general perceptions of control and a range of other covariates, low job control remained significantly associated with an increased risk of common mental disorder. This strengthens evidence that job control is an important contributor to poor mental health, independent of individual differences. Promoting employee job control is an evidence-supported approach to enhance mental health.

Affiliation: Centre for Mental Health, Melbourne School of Population and Global Health, The University of Melbourne, Parkville, Victoria 3052, Australia. tiffany.too@unimelb.edu.au

Refers to the following texts of the Journal: 2002;28(2):94-108 2006;32(6):443-462

Key terms: association; Australia; common mental disorder; control; depression; job control; job stressor; longitudinal cohort; mental disorder; mental health; psychosocial; stress

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31805200

Too LS, Leach L, Butterworth P. Is the association between poor job control and common mental disorder explained by general perceptions of control? Findings from an Australian longitudinal cohort. Scand J Work Environ Health. 2020;46(3):311-320. doi:10.5271/sjweh.3869

Correspondence to: Dr Lay San Too, Centre for Mental Health, Melbourne School of Population and Global Health, The University of Melbourne, Parkville, Victoria 3052, Australia. [E-mail: tiffany.too@unimelb.edu.au]

Footnote

1 Centre for Mental Health, Melbourne School of Population and Global Health, The University of Melbourne, Parkville, Victoria, Australia.

2 Centre for Research on Ageing, Health &Wellbeing, Research School of Population Health, The Australia National University, Canberra ACT, Australia.

3 National Centre for Epidemiology and Population Health, Research School of Population Health, The Australia National University, Canberra ACT, Australia.

4 Melbourne Institute of Applied Economic and Social Research, The University of Melbourne, Parkville, Victoria, Australia. These authors contributed equally to this work.

References

References

1. Vos T, 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 Dec;380(9859):2163-96. https://doi. org/10.1016/S0140-6736(12)61729-2.

2. Dollard M, Bailey T, McLinton S, Richards P, McTernan W, Taylor A et al. The Australian Workplace Barometer: report on psychosocial safety climate and worker health in Australia. Magill, SA: University of South Australia; 2012.

3. Theorell T, Hammarström A, Aronsson G, Träskman Bendz L, Grape T, Hogstedt C et al. A systematic review including meta-analysis of work environment and depressive symptoms. BMC Public Health 2015 Aug;15:738. https:// doi.org/10.1186/s12889-015-1954-4.

4. Stansfeld S, Candy B. Psychosocial work environment and mental health-a meta-analytic review. Scand J Work Environ Health 2006 Dec;32(6):443-62. https://doi. org/10.5271/sjweh.1050.

5. Nieuwenhuijsen K, Bruinvels D, Frings-Dresen M. Psychosocial work environment and stress-related disorders, a systematic review. Occup Med (Lond) 2010 Jun;60(4):277-86. https://doi.org/10.1093/occmed/kqq081.

6. Bonde JP. Psychosocial factors at work and risk of depression: a systematic review of the epidemiological evidence. Occup Environ Med 2008 Jul;65(7):438-45. https://doi.org/10.1136/oem.2007.038430.

7. Karasek RA. Job Demands, Job Decision Latitude, and Mental Strain: implications for Job Redesign. Adm Sci Q 1979;24:285-308. https://doi.org/10.2307/2392498.
8. Stansfeld SA, Shipley MJ, Head J, Fuhrer R. Repeated job strain and the risk of depression: longitudinal analyses from the Whitehall II study. Am J Public Health 2012 Dec;102(12):2360-6. https://doi.org/10.2105/AJPH.2011.300589.
9. Wang J, Schmitz N, Dewa C, Stansfeld S. Changes in perceived job strain and the risk of major depression: results from a population-based longitudinal study. Am J Epidemiol 2009 May;169(9):1085-91. https://doi.org/10.1093/aje/ kwp037.
10. Åhlin JK, Westerlund H, Griep Y, Magnusson Hanson LL. Trajectories of job demands and control: risk for subsequent symptoms of major depression in the nationally representative Swedish Longitudinal Occupational Survey of Health (SLOSH). Int Arch Occup Environ Health 2018 Apr;91(3):263-72. https://doi.org/10.1007/s00420-0171277-0.
11. de Lange AH, Taris TW, Kompier MA, Houtman IL, Bongers PM. Effects of stable and changing demand-control histories on worker health. Scand J Work Environ Health 2002 Apr;28(2):94-108. https://doi.org/10.5271/sjweh.653.
12. Harvey SB, Sellahewa DA, Wang MJ, Milligan-Saville J, Bryan BT, Henderson M et al. The role of job strain in understanding midlife common mental disorder: a national birth cohort study. Lancet Psychiatry 2018 Jun;5(6):498506. https://doi.org/10.1016/S2215-0366(18)30137-8.
13. Butterworth P, Leach LS, Strazdins L, Olesen SC, Rodgers B, Broom DH. The psychosocial quality of work determines whether employment has benefits for mental health: results from a longitudinal national household panel survey. Occup Environ Med 2011 Nov;68(11):806-12. https://doi. org/10.1136/oem.2010.059030.
14. Leach LS, Butterworth P, Strazdins L, Rodgers B, Broom DH, Olesen SC. The limitations of employment as a tool for social inclusion. BMC Public Health 2010 Oct;10:621. https://doi.org/10.1186/1471-2458-10-621.
15. Stansfeld SA, Fuhrer R, Shipley MJ, Marmot MG. Work characteristics predict psychiatric disorder: prospective results from the Whitehall II Study. Occup Environ Med 1999 May;56(5):302-7. https://doi.org/10.1136/oem.56.5.302.
16. Bentley RJ, Kavanagh A, Krnjacki L, LaMontagne AD. A Longitudinal Analysis of Changes in Job Control and Mental Health. Am J Epidemiol 2015 Aug;182(4):328-34. https://doi.org/10.1093/aje/kwv046.
17. Butterworth P, Leach LS, Rodgers B, Broom DH, Olesen SC, Strazdins L. Psychosocial job adversity and health in Australia: analysis of data from the HILDA Survey. Aust N Z J Public Health 2011 Dec;35(6):564-71. https://doi.org/10.1111/j.1753-6405.2011.00771.x.
18. Clark C, Pike C, McManus S, Harris J, Bebbington P, Brugha T et al. The contribution of work and non-work stressors to common mental disorders in the 2007 Adult Psychiatric Morbidity Survey. Psychol Med 2012 Apr;42(4):829-42. https://doi.org/10.1017/S0033291711001759.
19. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007 Oct;370(9596):1453-7. https://doi. org/10.1016/S0140-6736(07)61602-X.
20. Anstey KJ, Christensen H, Butterworth P, Easteal S, Mackinnon A, Jacomb T et al. Cohort profile: the PATH through life project. Int J Epidemiol 2012 Aug;41(4):95160. https://doi.org/10.1093/ije/dyr025.
21. Goldberg D, Bridges K, Duncan-Jones P, Grayson D. Detecting anxiety and depression in general medical settings. BMJ 1988 Oct;297(6653):897-9. https://doi. org/10.1136/bmj.297.6653.897.
22. Kiely KM, Butterworth P. Validation of four measures of mental health against depression and generalized anxiety in a community based sample. Psychiatry Res 2015 Feb;225(3):291-8. https://doi.org/10.1016/j.psychres.2014.12.023.
23. Bosma H, Marmot MG, Hemingway H, Nicholson AC, Brunner E, Stansfeld SA. Low job control and risk of coronary heart disease in Whitehall II (prospective cohort) study. BMJ 1997 Feb;314(7080):558-65. https://doi.org/10.1136/bmj.314.7080.558.
24. Butterworth P, Leach LS, McManus S, Stansfeld SA. Common mental disorders, unemployment and

psychosocial job quality: is a poor job better than no job at all? Psychol Med 2013 Aug;43(8): 1763-72. https://doi.org/10.1017/ S0033291712002577.
25. Pearlin LI, Schooler C. The structure of coping. J Health Soc Behav 1978 Mar;19(1):2-21. https://doi.org/10.2307/2136319.
26. Butterworth P, Rodgers B, Windsor TD. Financial hardship, socio-economic position and depression: results from the PATH Through Life Survey. Soc Sci Med 2009 Jul;69(2):229-37. https://doi.org/10.1016/j.socscimed.2009.05.008.
27. Stansfeld SA, Clark C, Caldwell T, Rodgers B, Power C. Psychosocial work characteristics and anxiety and depressive disorders in midlife: the effects of prior psychological distress. Occup Environ Med 2008 Sep;65(9):634-42. https://doi.org/10.1136/oem.2007.036640.
28. Hatch SL, Harvey SB, Maughan B. A developmentalcontextual approach to understanding mental health and wellbeing in early adulthood. Soc Sci Med 2010 Jan;70(2):2618. https://doi.org/10.1016/j.socscimed.2009.10.005.
29. Parker G. Parental characteristics in relation to depressive disorders. Br J Psychiatry 1979 Feb;134:138-47. https://doi. org/10.1192/bjp.134.2.138.
30. Rodgers B. Reported parental behaviour and adult affective symptoms. 1. Associations and moderating factors. Psychol Med 1996 Jan;26(1):51-61. https://doi.org/10.1017/ S0033291700033717.
31. Kessler RC, Magee WJ. Childhood adversities and adult depression: basic patterns of association in a US national survey. Psychol Med 1993 Aug;23(3):679-90. https://doi. org/10.1017/S0033291700025460.
32. Henderson AS, Jorm AF, Korten AE, Jacomb P, Christensen H, Rodgers B. Symptoms of depression and anxiety during adult life: evidence for a decline in prevalence with age. Psychol Med 1998 Nov;28(6):1321-8. https://doi. org/10.1017/S0033291798007570.
33. National Health and Medical Research Council. Australian Alcohol Guidelines: Health Risks and Benefits. Canberra: Department of Health and Ageing; 2001.
34. Saunders JB, Aasland OG, Babor TF, de la Fuente JR, Grant M. Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption-II. Addiction 1993 Jun;88(6):791-804. https://doi. org/10.1111/j.1360-0443.1993.tb02093.x.
35. Marmot MG, Smith GD, Stansfeld S, Patel C, North F, Head J et al. Health inequalities among British civil servants: the Whitehall II study. Lancet 1991 Jun;337(8754):1387-93. https://doi.org/10.1016/0140-6736(91)93068-K.
36. Fitzmaurice GM, Laird NM, Ware JH. Applied Longitudinal Analysis. 2nd Edition. New Jersey, Wiley; 2011.
37. Egan M, Bambra C, Thomas S, Petticrew M, Whitehead M, Thomson H. The psychosocial and health effects of workplace reorganisation. 1. A systematic review of organisationallevel interventions that aim to increase employee control. J Epidemiol Community Health 2007 Nov;61(11):945-54. https://doi.org/10.1136/jech.2006.054965.
Received for publication: 8 October 2019

DETAILS

Subject:	Mental health; Mental depression; Mental health care; Personality; Regression analysis; Regression models; Mental disorders; Questionnaires; Autonomy; Statistical analysis; Confidence intervals; Occupational health; Social interactions; Control methods; Adults; Occupational stress; Employment; Employees; Anxiety
Business indexing term:	Subject: Occupational stress Employment Employees
Location:	United Kingdom--UK
Company / organization:	Name: Australian National University; NAICS: 611310

Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	311-320,311A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Wor k, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3869
ProQuest document ID:	2406985346
Document URL:	https://www.proquest.com/scholarly-journals/is-association-between-poor-job-control-common/docview/2406985346/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2023-03-06
Database:	Public Health Database

Although a valuable method in occupational epidemiology, job-exposure matrices are no magic

fix

Peters, S [1] [1] Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands. s.peters@uu.nl

ABSTRACT (ENGLISH)

Peters discusses the job-exposure matrices (JEM). JEM are a common method for exposure assessment in occupational epidemiology. A recent review on methods for retrospective exposure assessment in the general population revealed that more than a quarter of the studies on cancer applied a JEM. Where JEM originally assigned exposures at a qualitative or semi-quantitative level based on expert ratings, quantitative exposure estimates can also be derived when measurements are used to calibrate these ratings. A JEM typically consists of job and exposure axes. The major advantage of JEM is that job histories can be translated into specific exposures in a systematic and unbiased way. It is basically a computerized linkage of exposure estimates to job codes, and, as such, JEM represent a highly efficient and reproducible methodology. This way, a standardized exposure assessment within and between studies can be guaranteed, and any misclassification is expected to be non-differential with respect to the health outcome. Once developed, a JEM is relatively easy to apply and less costly than case-by-case expert assessment.

FULL TEXT

Headnote

Key terms: editorial; epidemiology; JEM; job-exposure matrix; method; methodology; occupational epidemiology

Job-exposure matrices (JEM) are a common method for exposure assessment in occupational epidemiology. The first JEM were described in the early 1980s (1,2) and have been used in a wide range of settings ever since. A recent review on methods for retrospective exposure assessment in the general population revealed that more than a quarter of the studies on cancer applied a JEM (3). Where JEM originally assigned exposures at a qualitative or semi-quantitative level based on expert ratings, quantitative exposure estimates can also be derived when measurements are used to calibrate these ratings (4-6).

A JEM typically consists of job and exposure axes. The major advantage of JEM is that job histories can be translated into specific exposures in a systematic and unbiased way. It is basically a computerized linkage of exposure estimates to job codes, and, as such, JEM represent a highly efficient and reproducible methodology. This way, a standardized exposure assessment within and between studies can be guaranteed, and any misclassification is expected to be non-differential with respect to the health outcome. Once developed, a JEM is relatively easy to apply and less costly than case-by-case expert assessment.

These benefits make JEM a particularly useful instrument for exposure assessment in large-scale, general population studies. Such studies (eg, based on register data) permit collection of full occupational histories and enable the study of rare diseases or subtypes. Subjects have typically worked in a wide variety of occupations and industries. Detailed exposure information, which can more easily be collected in industry-based cohorts, is often not available. For register-based cohorts, collected occupational histories are also typically limited to the basic information of job titles and industries. Using JEM, exposures can be assessed for many agents and stressors, based solely on job titles.

The DOC·X project is a good example of the use of register data in occupational epidemiology (7). The large number of subjects - the full working population of Denmark for several decades - offers unique opportunities for studying new associations between a variety of exposures and various health outcomes. Individual data from several databases, including health and labour registries, were linked by a personal identifier. For each cohort member, job title and industry have been annually registered and coded (7). Subsequently, the project has been linking a series of JEM to this nationwide cohort to assess several kinds of occupational exposures. A couple of these efforts have been published in this issue of the Scandinavian Journal of Work, Environment and Health to assess the association between physical activities at work and acute myocardial infarction (8) and the risk of work-related hand eczema in relation to wet work (9). It is impossible to go back to all individuals in this cohort to collect detailed information on their occupations: firstly because part of the cohort has died over the years but also due to practical reasons given the large numbers. So, by applying JEM, the Danes make the best use of the information available in their registry data.

The ease of using a JEM, by simply assigning exposures based on job titles, also has a flipside. By design, a JEM allocates the same exposure estimates to all workers with the same job title. This aspect represents the main drawback since it is well-recognized that there can be substantial inter-individual variability (10). In other words, a JEM completely dismisses exposure heterogeneity between workers in similar jobs, as has also been acknowledged by the authors of the DOC·X studies (8, 9).

Heterogeneity between workers may be larger for some types of exposures than others, particularly when exposures are largely determined by specific tasks. To illustrate, when assessing welding fumes, job title alone does not provide information on different tasks and circumstances that influence the level and frequency of exposure to welding fumes (11). For exposures related to tasks like welding, decreasing or pesticide application - but also exposures such as shift work or certain psychosocial working conditions - exposure assessment based on job title alone may not be sufficient. Thus, researchers need to critically evaluate for each given exposure, if that exposure can be reasonably assessed on the job group level or if further assessment on the workplace, work unit or individual-worker level is needed.

A large part of heterogeneity is determined by the workers' behavior (12). Although this is virtually impossible to take into account in a JEM, some of the exposure heterogeneity may be accounted for by adding more detail, ie, by expanding the number of axes of the JEM. For example, an industry-axis, a time dimension, or region-, sex- and age-specific estimates may help explain part of the exposure heterogeneity. Importantly, this type of information is also typically available in the large studies where the JEM are being applied to. The JEM for wet work used by Lund et al (9) provided sex-specific estimates. A similar effort has been described for mechanical and psychosocial work exposures in Norway (13).

In addition to within-job (ie, between-worker) variability, exposures may have large temporal (ie, withinworker) variability. Levels can vary from day-to-day or over the course of the work day, the variability of which is not captured in a JEM. When studying acute health effects, for example, short-term high exposures may be more relevant than the annual average or cumulative levels and a JEM may not provide the appropriate assessment.

Many different JEM, in all forms and shapes, have been developed over the last 40 years. Due to the lack of a gold standard, JEM cannot be truly validated. Several studies, however, have described the performance of JEM (14-16). For asbestos, for instance, poor agreement between different JEM has been reported, indicating variable performance (14). Exposure assessment methods can also be evaluated using known associations with health outcomes. Using lung cancer case-control data, comparisons with other methods showed that a JEM for asbestos could outperform self-reported exposure (16) and perform as well as case-by-case expert assessment in a multicenter study (15). Yet, as indicated above, the performance of a JEM will depend on the exposure and effect of interest.

Improvement in the use of JEM could be achieved by harmonizing existing JEM. A harmonized JEM, which provides a standardized exposure assessment across regions and time periods, would be highly valuable for pooled analyses. Such large-scale analyses will offer unique opportunities to study exposure-disease associations that have been understudied until now due to lack of statistical power. JEM will be invaluable instruments to such (exploratory) exercises.

Derivation of exposure-response relations requires quantification of exposure. Development of more quantitative JEM, as first described for the multinational SYNERGY project on lung cancer (4) and the Shanghai Women's

Health Study (6), may further increase the impact of occupational studies. However, a quantitative JEM will still have the same limitation of assuming homogeneity within jobs and large amounts of (measurement) data are needed to develop a quantitative JEM. Data mining techniques could be explored to make better use of existing data sources for high-quality exposure assessment.

The coding of job titles is another major challenge related to the use of JEM. Manual coding of each individual's job history in large epidemiological studies is a very time-consuming task. As a result, many of these studies are not used to their full potential for occupational health outcomes. Further improvement could therefore be achieved by systems that automatically translate free text into occupational codes, increasing the efficiency and feasibility of investigating occupational risk factors (using JEM) in large-scale epidemiological studies. Efforts in developing automatic coding in the US have shown agreements with manual coding of around 50% (17, 18).

Automated coding systems would not be applicable to most registry data, however, since job information is only available as a code. For pooling these registry data with other data, or for application of another JEM, crosswalks between systems can be the solution. In addition to differences between human coders, crosswalks may also introduce disagreement between codes and actual jobs, possibly leading to further misclassification of exposure. Interestingly, within DOC·X it was shown that errors in job coding had limited effect on the exposure assessment of wood dust, lifting, standing/walking, arm elevation, and noise (19). Previous studies also reported that the effects of disagreements in job coding generally diminish in the exposure assessment stage (12, 20).

Specificity is crucial when the prevalence of occupational exposure is low, which is often the case in the general population because possible associations may otherwise be severely underestimated. When exposures are more prevalent, sensitivity becomes more important (12). Since the performance of a JEM is also determined by the between-worker (ie, within job) and between-job variance, the level of detail of the job classification plays an important role. Occupational classification systems have primarily been developed from a social-economic perspective. These systems, either international or national coding schemes, are therefore not necessarily reflecting exposure categories in the best way. Developing new or adjusted coding systems for exposure assessment may help moving the occupational health field forward.

Several research initiatives are currently working on such improvements in the use of JEM, including the Network on the Coordination and Harmonisation of European Occupational Cohorts (OMEGA-NET, omeganetcohorts.eu) and the Exposome Project for Health and Occupational Research (EPHOR, www.ephor-project.eu).

In conclusion, a JEM can be a very handy tool for exposure assessment in occupational epidemiology, particularly in large-scale studies with limited occupational information. When selecting the most suitable exposure assessment method, however, researchers should always remain critical. Know when a JEM has added value and recognize its limitations.

Sidebar

Dr Susan Peters
Institute for Risk Assessment Sciences,
Utrecht University,
Utrecht, The Netherlands
[e-mail: s.peters@uu.nl]

References

References

1. 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(ll):722-6.
2. 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(11):777-83. https://doi.org/10.1136/oem.42.11.777
3. Ge CB, Friesen MC, Kromhout H, Peters S, Rothman N, Lan Q, et al. Use and Reliability of Exposure Assessment Methods in Occupational Case-Control Studies in the General Population: Past, Present, and Future. Ann Work Expo Health. 2018;62(9):1047-63. https://doi.org/10.1093/annweh/wxy080

4. Peters S, Vermeulen R, Portengen L, Olsson A, Kendzia B, Vincent R, et al. Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies. J Environ Monit. 2011;13(11):3262-8. https:// doi.org/10.1039/c1em10628g
5. Peters S, Vermeulen R, Portengen L, Olsson A, Kendzia B, Vincent R, et al. SYN-JEM: A Quantitative Job-Exposure Matrix for Five Lung Carcinogens. Ann Occup Hyg. 2016;60(7):795-811. https://doi.org/10.1093/annhyg/mew034
6. Friesen MC, Coble JB, Lu W, Shu XO, Ji BT, Xue S, et al. Combining a job-exposure matrix with exposure measurements to assess occupational exposure to benzene in a population cohort in shanghai, china. Ann Occup Hyg. 2012;56(1):80-91. https://doi.org/10.1136/ oemed-2011-100382.81
7. Flachs EM, Petersen SEB, Kolstad HA, Schlunssen V, Svendsen SW, Hansen J, et al. Cohort Profile: DOC·X: a nationwide Danish occupational cohort with eXposure data - an open research resource. Int J Epidemiol. 2019;48(5):1413-k. https://doi.org/10.1093/ije/ dyz110
8. Bonde JPE, Flachs EM, Madsen IE, Petersen SB, Andersen JH, Hansen J, et al. Acute myocardial infarction in relation to physical activities at work: a nationwide follow-up study based on job-exposure matrices. Scand J Work Environ Health. 2020;46(3):268-277. https://doi.org/10.5271/sjweh.3863
9. Lund T, Petersen SB, Flachs EM, Ebbehoj NE, Bonde JP, Agner T. Risk of work-related hand eczema in relation to wet work exposure. Scand J Work Environ Health. 2020. https://doi.org/10.5271/sjweh.3876
10. Kromhout H, Symanski E, Rappaport SM. A comprehensive evaluation of within- and between-worker components of occupational exposure to chemical agents. Ann Occup Hyg. 1993;37(3):253-70.
11. IARC Working Group. Volume 118: Welding, Indium Tin Oxide, Molybdenum Trioxide.: IARC Monogr Eval Carcinog Risks Hum; 2018.
12. Kromhout H, Vermeulen R. Application ofjob-exposure matrices in studies of the general population. Some clues to their performance. European Respiratory Review. 2001;11:80-90.
13. Hanvold TN, Sterud T, Kristensen P, Mehlum IS. Mechanical and psychosocial work exposures: the construction and evaluation of a gender-specific job exposure matrix (JEM). Scand J Work Environ Health. 2019;45(3):239-47. https://doi.org/10.5271/sjweh.3774
14. Offermans NS, Vermeulen R, BurdorfA, Peters S, Goldbohm RA, Koeman T, et al. Comparison of expert and job-exposure matrix-based retrospective exposure assessment of occupational carcinogens in The Netherlands Cohort Study. Occup Environ Med. 2012;69(10):74551. https://doi.org/10.1136/oemed-2011-100556
15. Peters S, Vermeulen R, Cassidy A, Mannetje A, van Tongeren M, Boffetta P, et al. Comparison of exposure assessment methods for occupational carcinogens in a multi-centre lung cancer case-control study. Occup Environ Med. 2011;68(2):148-53. https://doi. org/10.1136/oem.2010.055608
16. Hardt JS, Vermeulen R, Peters S, Kromhout H, McLaughlin JR, Demers PA. A comparison of exposure assessment approaches: lung cancer and occupational asbestos exposure in a population-based case-control study. Occup Environ Med. 2014;71(4):282-8. https:// doi.org/10.1136/oemed-2013-101735
17. Russ DE, Ho KY, Colt JS, Armenti KR, Baris D, Chow WH, et al. Computer-based coding of free-text job descriptions to efficiently identify occupations in epidemiological studies. Occup Environ Med. 2016;73(6):417-24. https://doi.org/10.1136/oemed-2015-103152
18. Burstyn I, Slutsky A, Lee DG, Singer AB, An Y, Michael YL. Beyond crosswalks: reliability of exposure assessment following automated coding of free-text job descriptions for occupational epidemiology. Ann Occup Hyg. 2014;58(4):482-92.
19. Petersen SB, Flachs EM, Svendsen SW, Marott JL, Budtz-Jorgensen E, Hansen J, et al. Influence of errors in job codes on job exposure matrix-based exposure assessment in the register-based occupational cohort DOC·X. Scand J Work Environ Health. 2020;46(3):259267. https://doi.org/10.5271/sjweh.3857
20. Koeman T, Offermans NS, Christopher-de Vries Y, Slottje P, Van Den Brandt PA, Goldbohm RA, et al. JEMs and incompatible occupational coding systems: effect of manual and automatic recoding of job codes on exposure assignment. Ann Occup Hyg. 2013;57(1):107-14.

DETAILS

Subject:	Population; Womens health; Ratings; Lung cancer; Epidemiology; Occupational health; Job titles; Studies; Workers; Exposure; Methods; Codes; Job classification; Occupations; Employment; Occupational exposure
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	231-234,231A
Publication year:	2020
Publication date:	2020
Section:	Editorial
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Editorial
DOI:	https://doi.org/10.5271/sjweh.3894
ProQuest document ID:	2406985313
Document URL:	https://www.proquest.com/scholarly-journals/although-valuable-method-occupational/docview/2406985313/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2020-05-27

Precarious employment in occupational health – an OMEGA-NET working group position paper

Bodin, Theo; Çağlayan, Çiğdem; Garde, Anne Helene; Gnesi, Marco; Jonsson, Johanna; Kiran, Sibel; Kreshpaj, Bertina; Leinonen, Taina; Mehlum, Ingrid S; Nena, Evangelia; Orellana, Cecilia; Peckham, Trevor; Seixas, Noah; Vanroelen, Christophe; Julia, Mireia

ABSTRACT (ENGLISH)

Objectives The aims of this position paper are to (i) summarize research on precarious employment (PE) in the context of occupational health; (ii) develop a theoretical framework that distinguishes PE from related concepts and delineates important contextual factors; and (iii) identify key methodological challenges and directions for future research on PE and health. Methods This position paper is the result of a working group consisting of researchers from the EU, Turkey and the USA, who have discussed the issue over the course of six months (October 2018-April 2019), meeting both online and face-to-face on several occasions. Results The lack of a common theoretical framework of PE hinders it from becoming an established part of occupational and public health research. There are also issues regarding operationalization in surveys and registers. Further, previous research on PE and health suffers from methodological limitations including inadequate study designs and biased assessments of exposure and outcomes. PE is highly dependent on contextual factors and cross-country comparison has proven very difficult. We also point to the uneven social distribution of PE, ie, higher prevalence among women, immigrants, young and low educated. We propose a theoretical framework for understanding precarious employment as a multidimensional construct. Conclusions A generally accepted multidimensional definition of PE should be the highest priority. Future studies would benefit from improved exposure assessment, temporal resolution, and accounting for confounders, as well as testing possible mechanisms, eg, by adopting multi-level and intersectional analytical approaches in order to understand the complexity of PE and its relation to health. Key terms employment condition; non-standard employment; social determinant of health; working condition.

FULL TEXT

Headnote

Objectives The aims of this position paper are to (i) summarize research on precarious employment (PE) in the context of occupational health; (ii) develop a theoretical framework that distinguishes PE from related concepts and delineates important contextual factors; and (iii) identify key methodological challenges and directions for future research on PE and health.

Methods This position paper is the result of a working group consisting of researchers from the EU, Turkey and the USA, who have discussed the issue over the course of six months (October 2018-April 2019), meeting both online and face-to-face on several occasions.

Results The lack of a common theoretical framework of PE hinders it from becoming an established part of occupational and public health research. There are also issues regarding operationalization in surveys and registers. Further, previous research on PE and health suffers from methodological limitations including inadequate study designs and biased assessments of exposure and outcomes. PE is highly dependent on contextual factors and

cross-country comparison has proven very difficult. We also point to the uneven social distribution of PE, ie, higher prevalence among women, immigrants, young and low educated. We propose a theoretical framework for understanding precarious employment as a multidimensional construct.

Conclusions A generally accepted multidimensional definition of PE should be the highest priority. Future studies would benefit from improved exposure assessment, temporal resolution, and accounting for confounders, as well as testing possible mechanisms, eg, by adopting multi-level and intersectional analytical approaches in order to understand the complexity of PE and its relation to health.

Key terms employment condition; non-standard employment; social determinant of health; working condition.

There is a growing recognition of the myriad ways in which employment and work contribute to the health of populations. In addition to traditional occupational hazards, such as dusts, chemicals, injury risks and psychosocial stressors, there is an increasing appreciation of how aspects of the employment relationship, referring to the terms and conditions by which an organization (business, public, or non-profit entity) pays someone to work for them, can be a social determinant of health. Various lines of evidence suggest that the overall quality of employment relationships in developed economies has significantly degraded in the last decades (1, 2). Moreover, because employment quality is commonly associated with sociodemographic profiles, these trends have led to mounting concern about the role of employment in contributing to health disparities across working populations (3). These concerns have been incorporated into a broad conception of an array of employment conditions through the term 'precarious employment' (PE). However, despite the growing use of the term, and the multiple efforts to define this concept, no clear consensus has emerged. Thus, research of the health implications of PE has been hampered.

The EU-funded Network on the Coordination and Harmonisation of European Occupational Cohorts, OMEGA-NET (omeganetcohorts.eu), recognizes the importance of the issue and supports the development of epidemiological research on PE. This position paper is the result of a working group consisting of researchers from the EU, Turkey and the USA, who have discussed the issue over the course of six months from October 2018 to April 2019. It is hoped that through refinement of the PE concept, a clearer consensus on its operationalization can be adopted for its integration into research on the health of working populations of Europe and beyond. Further, by addressing issues of PE in the context of these large cohort studies, a research agenda can be developed to focus research on questions with the greatest potential for improving the health and well-being of a large number of workers.

Specifically, the aims of this paper are to (i) summarize research on PE in the context of occupational health; (ii) develop a theoretical framework that distinguishes PE from related concepts and delineates important contextual factors; and (iii) identify key methodological challenges and directions for future research on PE and health.

Lack of a common definition of precarious employment

Despite thriving in fields such as economics and sociology, there are still barriers preventing PE from becoming an established part of occupational and public health research some of which have recently been pointed out in an editorial in this journal (4).

There is substantial confusion when it comes to the concept of PE, as many related terms are used interchangeably: 'the precariat', 'precarious work' or simply 'precarity' or 'precariousness'. In the EU, 'atypical' or 'nonstandard' forms of employment have been used widely instead of, or as synonyms for, PE, whereas in the US the term 'contingent work' is more common (5). Another concept used in the occupational health literature is 'employment quality', which refers to the employment conditions and employment relations together (6). Employment quality can be conceived as a continuum, where PE is at the disadvantaged end due to an accumulation of unfavorable facets of employment quality.

Fundamentally, there is no universally accepted definition of PE that can transcend sociopolitical and historical context. Starting with the foundational work of Rodgers &Rodgers in the 1980s (7), four main dimensions of PE were identified: (i) employment instability, (ii) employment insecurity (limited control, collective or individual, over working conditions, wages and place of work), (iii) erosion of workers' protection and (iv) low material rewards. Building on this work, several researchers and institutions have adopted and developed their own definitions and operationalizations and studied these within a public health context (7-12). However, none of these have gained enough traction from researchers and practitioners to become the "standard definition". Therefore, PE has not been integrated into routine surveillance instruments, such as labor force or working conditions surveys, making longitudinal, population-based studies on the topic rare and international comparison infeasible. From a public health perspective, compared to research on psychosocial work environment launched by Karasek in 1979 (13), research on PE has achieved far less attention as an "occupational health threat" from practitioners and policy-makers. In public health research, PE has often been reduced to 'single dimensions' (of employment quality), such as temporary or part-time employment. Too often, it has been used synonymously for self-perceived job insecurity, a psychological (cognitive and/or affective) phenomenon (14), which we consider a consequence rather than an objective measure of PE.

Previous operationalization and measurement

To date, only two validated questionnaires have been developed for the sole purpose of measuring PE in a public health context. Researchers affiliated with the GREDS-EMCONET (Health Inequalities Research Group - Employment Conditions Network) in Barcelona developed the Employment Precariousness Scale (EPRES), which includes six dimensions: "temporariness" (contract duration), "disempowerment" (level of negotiation of employment conditions), "vulnerability" (defenselessness to authoritarian treatment), "wages" (low or insufficient; possible economic deprivation), "rights" (such as paid vacations, parental leave, sickleave benefits and pensions), and "exercise rights" (powerlessness, in practice, not being able to exercise the workplace rights listed previously without obstacles) (11). So far, the EPRES scale has only been employed in studies of working populations in Spain (15, 16), Chile (17), and Sweden (18). The only other purpose-specific survey instrument to measure PE is from Canada. In the longitudinal survey Poverty and Employment Precarity in Southern Ontario (PEPSO) 2011-2014, the Employment Precarious Index was created based on ten questions covering: income level, income security, employment security, schedule predictability, contract type, employment-related benefits, fear of raising concerns at the workplace (lack of rights/vulnerability), and receiving salary in cash (risk factor for undeclared salary in the Canadian context) (19).

Due to the challenges and costs of creating and validating purpose-specific surveys, many studies have attempted to exploit existing data to characterize PE using proxy indicators within labor, economic, health, or social surveys. The list of surveys used to study PE (or related constructs) and health is long; some notable examples include the European Working Conditions Survey (6, 20-23), European Labour Force Survey (24), Gender and Generations Study in Belgium (25), Catalan Working Conditions Survey in Catalonia (16), the US General Social Survey (26), and Canadian Survey of Labor and Income Dynamics (27). All but the last of these are cross-sectional studies, limiting the scientific value of resulting analyses to hypothesis generation and theory development. The few extant examples of longitudinal analyses provide more support for the causal relationship - for example, by controlling for baseline health or examining employment trajectories (27, 28) - but have limited generalizability and comparability to other studies using other sets of questions (29). Although studies employing secondary data analysis are inherently limited, the use of proxies facilitates the development of large-scale and cross-national evidence using existing data sources (20).

Records from government agencies, hospitals, large employers, insurance firms or other organizations can contain employment-related variables, which could be used to operationalize PE. A few studies have used register data to study employees who have a large number of contracts (30), frequent job changes (31), or fixedterm contracts (32-34). Ongoing work to operationalize a multi-dimensional construct of PE in routine register data is under way in Sweden and Denmark, and attempts have also been made in Belgium.

In addition to choice of indicators, several approaches to operationalizing a multidimensional construct of PE are present in the health literature. One approach is to include multiple indicators of PE within multivariable regression analysis (27). This approach thus examines associations between individual indicators and health, while controlling for all others. A second, and the most common approach is to create a composite or summed scale variable, measuring a worker's relative position along a continuum of low to high precariousness (35, 36). This approach can be used to examine whether health is associated with an accumulation of poor employment conditions. A third approach is to construct a typology of employment arrangements, conceptualizing jobs as packages of employment features and thus allowing for examination whether specific patterns of exposure are associated with health. Studies using a typological approach have most commonly used latent class analysis to model types of employment arrangements (6, 25, 26). We do not recommend a specific approach, but encourage researchers to make careful considerations when designing a study.

Precarious employment and health

Despite the limited agreement on definition and operationalization of PE, a growing number of studies have focused on the health effects of PE during the last decades. Recent systematic reviews show that multidimensional indicators as well as various separate dimensions of PE may be linked to an array of health issues including mental and physical ill-health (3, 29) and occupational injuries (37), as well as health-related behaviors such as higher levels of smoking (38) and lower access to healthcare (39). There are also studies showing associations between PE and higher risk of childlessness/postponed parenthood (40) and risk of disability pension (41). One study investigated relations with satisfaction with working conditions (6).

The mechanisms linking PE and health are not yet fully understood (20, 42, 43). Three main pathways have been suggested (i): working conditions with harmful health consequences are more frequently experienced by workers with PE (ii); poor employment conditions associated with PE may lead to adverse health outcomes by limiting worker's control over their professional and personal lives; and (iii) PE may produce incomes below the subsistence level, which may consequently affect various social determinants of health (eg, housing quality, adverse lifestyle etc.) (20).

Investigating the relation between PE and health is complicated because of bidirectional or reverse causation and health selection effects (44). In a recent review of longitudinal studies on PE and mental health, many studies had serious limitations in design, including measurement of exposure and outcomes at the same time-point and lack of appropriate baseline adjustments (29). Because employees may change employment status throughout life - and precarious employees even more so - using only one time-point for exposure measurement may result in misclassification of exposure, a problem which has only been handled in very few studies (28). Further, many survey-based studies suffer from the use of subjective measures of both exposure and outcomes adding to risk of common method bias (occurring eg, when both exposures and outcomes are self-reported).

Applying work-life trajectories would take several of the limitations in previous studies into account and has the potential to create a bridge to sociology, ethnography, and economics, where the process of precarisation is a major focal point of interest.

Although several studies have applied multidimensional constructs, most studies with stated aims to investigate the association between PE and health depend on single aspects of employment arrangements, such as non-standard or temporary employment contracts. Recent reviews have found no overall clear direction of associations between temporary contracts and mental health (29, 45) or occupational injuries (37). Yet, longitudinal studies applying various multidimensional exposure constructs have found stronger mental health effects of PE than those seen when studying parts of the phenomenon as single-item variables (29). This adds to the already strong case for applying a multi-dimensional approach with objective measures (46).

Labor market context and welfare regimes

Due to the lack of a common definition, relevant comparisons between countries and continents are extremely difficult. Based on multidimensional operationalizations in surveys in the EU, the prevalence of PE has been found to be higher in Southern and Eastern European countries and lower in the Nordic countries, although the detailed picture is more nuanced (47, 48).

In Anglo-Saxon or "liberal" welfare regimes such as the USA, the term "contingent work" is commonly used instead of PE. However, very few workers fall within this category (49), highlighting the fact that employers in these countries have little need or incentive to create explicitly temporary jobs, since open-ended contracts can easily be terminated. On the contrary, temporary employment is more common in East-Asian welfare regimes such as Korea and Japan (50), which are generally characterized by low levels of governmental intervention and investment in social welfare, less developed public service provision, and a strong reliance on family and the voluntary sector in welfare provision (51).

A strong welfare system can alleviate some of the effects of PE. However, in some countries with strong welfare systems, PE might increase the risk of not qualifying for social security schemes, as these were built to cater for workers in a "standard employment relation". The lack of social (and OHS) protection for precarious employees could further increase the differences in health and well-being. Strong welfare regimes have also developed in countries with strong unions and labor laws, which further confounds and complicates the study of these issues. Others have called for a systems approach (42), stating this is necessary to understand the interaction between social and institutional regulatory protection and PE.

Axes of inequality

Exploring the intersecting axes of inequality among those in PE is crucial to understanding both the social distribution of PE and its differential effects (52). Several studies have found a higher prevalence of PE among women, young workers, manual workers, and immigrants (22, 53). The more of these inequality characteristics that accumulate in the same person, the higher the prevalence of employment precariousness (36). One publication from Chile compared the association between psychological distress and PE and found it to be significantly higher in women (54).

Research gaps persist whether these inequalities in employment relationships contribute to gender differences in adverse health outcomes.

Standing (8) underlines how the migrant population covers a large share of the world's precariat. Studies have further shown how recently arrived migrants are more likely to be engaged in temporary and agency work and to have insecure and poor working conditions (55-57). Recently arrived migrants often have limited access to legal expertise, collective bargaining, and union representation, and consequently end up accepting the most precarious labor contracts, sometimes also informal employment (57-59).

Research agenda

Theoretical framework for a common definition. Despite a rapidly growing empirical and theoretical literature, a generally accepted multidimensional definition of PE is lacking - an issue of the highest priority. A critical first step to advancing research on PE and health is conceptual clarity. We propose a theoretical framework for understanding PE as a multidimensional construct where unfavorable features of employment quality accumulate in the same job (figure 1). Thus, conceptualization and measurement of PE for occupational health research occurs at the level of the employment relationship. Examples of important employment conditions that constitute this relationship are level of pay and other non-wage benefits, workplace rights and representation, and length or type of contract. We do not aim to list all possible aspects of employment relations that could be included, rather we encourage an open discussion on that matter.

The types of employment found in a labor market are influenced by global economic, technological, social, and political trends, such as globalization processes and weakening labor representation. These macro-level trends and factors are upstream and antecedent of PE, for example, having contributed to a general increase in the prevalence of sub-contracting, outsourcing, consulting, and newer forms of gig and platform work. Macro-level trends also interact with international and national labor rights legislation, regulations, and collective agreements.

From our theoretical framework, it follows that hazardous, boring or dissatisfying work should be seen as possible consequences of PE, rather than characteristics of precarious work itself. The same holds for psychological (cognitive and/or affective) perceptions of job insecurity, social precarisation (poverty, "life" insecurity, etc.) and adverse health outcomes, which we believe are conceptually on another level, downstream from the PE. Furthermore, the component of contractual instability, which is more related to job insecurity, could be addressed by measuring type of contract, objective treats to the continuity of employment.

We further highlight the importance of policy and social contexts, which may be key modifying (or moderating) factors that influence the nature of PE in specific contexts, as well as the PE-health relationship but that are not included in measurement of the construct. In other words, the nature and consequences of a given employment relationship may differ depending on contextual factors like regulatory protections or availability of social insurance, as well as across different sociodemographic groups and workers' social context.

Without a common definition of PE to guide operationalization of the concept, cross-study and crosscountry comparisons and meta-analyses will continue to be elusive.

Future research on PE and health would benefit from (i) an open and interdisciplinary process to reach consensus on a definition of PE and/or employment quality; (ii) guidelines for standardized reporting of data in order to increase the comparability between studies; and (iii) inclusion of a core set of questions into different panel surveys such as the European Working Conditions and Labour Force surveys, etc.

Intersectional and multi-level analysis

Using our proposed theoretical framework, we aim to clarify the various relevant levels of analyses, beginning with the level of the employment relationship. Moving upstream, analyses should continue to clarify the antecedents of different employment forms - both across jurisdictions and over time - to inform potential interventions and policy aimed at reducing the prevalence of PE. However, most research in occupational and public health in this area will be oriented downstream of the employment relationship. For instance, further analyses are needed to clarify mechanistic pathways leading to ill health, such as characteristics of the work environment, adequacy of job-related material rewards, and direct psychological impacts from PE relations. Further, it is important to account for policy and social contexts that are likely to modify/moderate these pathways. In particular, theory and evidence suggest that individual experiences of precariousness are heavily influenced by these contexts (52, 60). Ultimately, the goal of occupational health epidemiology is to identify job-related determinants of worker health; thus, distinguishing between the employment relationship and other factors is important to guide workplace and regulatory policy interventions. However, because of the complex and embedded nature of PE within multiple layers of context, we argue that a deeper understanding of the role of PE in producing health will occur when we disentangle the relationships across all of these levels as suggested in previous work (61). This approach differs from other research focused on the level of precarious workers or a precariat social class.

Better longitudinal studies for health

Research on PE and health lacks longitudinal studies of high-quality, ie, design, objective exposure and outcome measurement and standardized reporting of results. Thus, future research on PE and health would benefit from:

1.Improved exposure assessment, temporal resolution, and accounting for confounding:

* More longitudinal studies on PE (2, 4, 6) and health.
* Use of a combination of data sources to minimize reporting bias.
* Better resolution of timing of the exposure, eg, by examining employment trajectories. Studying employment trajectories can provide knowledge on how effects of PE accumulate across time, the transient or chronic nature of possible effects, and if these effects are modified by other factors (4).
* Better use of register data, providing information that is both objective and repeatedly measured, highly useful for operationalization.
* Careful considerations when selecting the sources of data on precarious employees. Precarious employees may be on hourly contracts, which can affect the registration of the outcome, eg, for occupational injuries, when the outcome is registered as days of absence due to injury (6).

2. Mechanisms and mediator studies:

* Detailed study on the mechanisms/pathways relating precariousness to (specific) health and well-being outcomes.
* Clinical studies with biological sampling should be seriously considered.

3. Studies on other outcomes, such as:

* Cardiovascular and respiratory diseases
* Associations with biomarkers of which relationship with stress-related diseases is demonstrated
* There are very few studies on the relation/coexistence of PE and hazardous work environment, a pathway that should be explored.

Concluding remarks

A commonly accepted multidimensional definition of PE should be one of the highest priorities in the occupational safety and health field. Adopting a multi-level and intersectional analytical approach in future studies is key to understanding the complex processes of PE and their relation to health.

Acknowledgments

The authors would like to thank OMEGA-NET core group for its support.

Funding statement

The European Union financed the work of this task group (COST Action CA16216). The funder had no role in its design, search and analysis, decision to publish, or preparation of the manuscript.

Ethics statement

This position paper does not require ethical approval

Conflicts of interest

The authors declare no conflicts of interest.

Sidebar

Despite the growing use of the term precarious employment, there is no consensus on a theoretical framework or definition. This hampers the study of the subject, especially in public and occupational health. We propose a theoretical framework for understanding precarious employment as a multidimensional construct where unfavourable features of employment quality accumulate in the same job. Future research should apply an intersectional and multi-level approach to analysis, with a focus on improving exposure assessment and investigating mechanisms.

Affiliation: Center for Occupational and Environmental Medicine, Solnavägen 4, SE-11364 Stockholm, Sweden. theo.bodin@ki.se

Refers to the following texts of the Journal: 2019;45(5):425-427 2019;45(5):429-443 2018;44(4):341-350 2014;40(4):343-352 2002;28(3):į91-į96

The following article refers to this text: 2020;46(3):235-247

Key terms: employment condition; non-standard employment; occupational health; OMEGA-NET; position paper; precarious employment; social determinant of health; working condition

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31735974

Bodin T, Çağlayan C, Garde AH, Gnesi M, Jonsson J, Kiran S, Kreshpaj B, Leinonen T, Mehlum IS, Nena E, Orellana C, Peckham T, Seixas N, Vanroelen C, Julia M. Precarious employment in occupational health - an OMEGA-NET working group position paper. Scand J Work Environ Health. 2020;46(3):321-329. doi:10.5271/sjweh.3860

Correspondence to: Theo Bodin, Center for Occupational and Environmental Medicine, Solnavägen 4, SE-11364 Stockholm, Sweden. [Email: theo.bodin@ki.se]

Footnote

1 Unit of Occupational Medicine, Institute of Environmental Medicine, Karolínska Institutet, Stockholm, Sweden.

2 Center for Occupational and Environmental Medicine, Stockholm Region, Stockholm, Sweden.

3 Kocaeli University, Faculty of Medicine, Department of Public Health, Kocaeli, Turkey.

4 National Research Centre for the Working Environment, Copenhagen, Denmark.

5 Department of Public Health, University of Copenhagen, Denmark.

6 Department of Public Health, Experimental Health and Forensic Medicine, University of Pavia, Pavia, Italy.

7 The Department of Occupational Health and Safety, Institute of Public Health, Hacettepe University, Ankara, Turkey.

8 Finnish Institute of Occupational Health, Helsinki, Finland.

9 National Institute of Occupational Health, Oslo, Norway.

10 Medical School, Democritus University of Thrace, Alexandroupolis, Greece.

11 Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, USA.

12 Interface Demography, Department of Sociology, Vrije Universiteit Brussel, Belgium.

13 Health Inequalities Research Group, Employment Conditions Knowledge Network (GREDS-EMCONET), Department of Political and Social Science, Universitat Pompeu Fabra, Barcelona, Spain.
14 Johns Hopkins University-Universitat Pompeu Fabra Public Policy Center, Barcelona, Spain.

References

References

1. Kalleberg AL. Good jobs, bad jobs: The rise of polarized and precarious employment systems in the United States, 1970s-2000s: Russell Sage Foundation; 2011.
2. Della Porta D, Silvasti T, Hänninen S, Siisiäinen M. The new social division: Making and unmaking precariousness: Springer; 2016.
3. Benach J, Vives A, Amable M, Vanroelen C, Tarafa G, Muntaner C. Precarious employment: understanding an emerging social determinant of health. Annu Rev Public Health 2014;35(1):229-53. https://doi.org/10.1146/annurevpublhealth-032013-182500.
4. Ervasti J, Virtanen M. Research strategies for precarious employment. Scand J Work Environ Health. 2019;45(5):4257. https://doi.org/10.5271/sjweh.3845.
5. Quinlan M. The 'Pre-Invention' of Precarious Employment: The Changing World of Work in Context. Econ Labour Relat Rev. 2012;23(4):3-24. https://doi.org/10.1177/10353046120 2300402.
6. Van Aerden K, Puig-Barrachina V, Bosmans K, Vanroelen C. How does employment quality relate to health and job satisfaction in Europe? A typological approach. Soc Sci Med. 2016;158:132-40. https://doi.org/10.1016/j. socscimed.2016.04.017.
7. Rodgers G, Rodgers J. Precarious jobs in labour market regulation: the growth of atypical employment in Western Europe: International Labour Organisation; 1989.
8. Standing G. The precariat: The new dangerous class: Bloomsbury Publishing; 2011.
9. International Labour Organization (ILO). From precarious work to decent work: outcome document to the workers' symposium on policies and regulations to combat precarious employment. Geneva: ILO, Bureau for Workers' Activities, 2012.
10. Tompa E, Scott-Marshall H, Dolinschi R, Trevithick S, Bhattacharyya S. Precarious employment experiences and their health consequences: towards a theoretical framework. Work. 2007;28(3):209-24.
11. Vives A, Amable M, Ferrer M, Moncada S, Llorens C, Muntaner C et al. The Employment Precariousness Scale (EPRES): psychometric properties of a new tool for epidemiological studies among waged and salaried workers. Occup Environ Med. 2010;67(8):548-55. https://doi. org/10.1136/oem.2009.048967.
12. Vosko LF. Precarious employment: Understanding labour market insecurity in Canada: McGill-Queen's University Press Quebec; 2006.
13. Karasek RA Jr. Job demands, job decision latitude, and mental strain: implications for job redesign. Adm Sci Q. 1979;24(2):285-308. https://doi.org/10.2307/2392498.
14. Shoss MK. Job Insecurity: An Integrative Review and Agenda for Future Research. J Manage. 2017 ;43(6): 191139. https://doi.org/10.1177/0149206317691574.
15. Vives A, Gonzalez F, Moncada S, Llorens C, Benach J. Measuring precarious employment in times of crisis: the revised Employment Precariousness Scale (EPRES) in Spain. Gac Sanit. 2015;29(5):379-82. https://doi.org/10.1016/j. gaceta.2015.06.008.
16. Benach J, Julia M, Tarafa G, Mir J, Molinero E, Vives A. La precariedad laboral medida de forma multidimensional: distribución social y asociación con la salud en Cataluña. [Multidimensional measurement of precarious employment: social distribution and its association with health in Catalonia (Spain)]. Gac Sanit. 2015;29(5):375-8. https://doi. org/10.1016/j.gaceta.2015.04.002.
17. Vives-Vergara A, González-López F, Solar O, BernalesBaksai P, González MJ, Benach J. Precarious employment in Chile: psychometric properties of the Chilean version of Employment Precariousness Scale in private sector workers. Cad Saude Publica. 2017;33(3):e00156215. https://doi. org/10.1590/0102-311x00156215.
18. Jonsson J, Stein M, Johansson G, Bodin T, Strömdahl S. A performance assessment of web-based respondent

driven sampling among workers with precarious employment in Sweden. PLoS One. 2019;14(1):e0210183. https://doi. org/10.1371/journal.pone.0210183.
19. Lewchuk W. Precarious jobs: where are they, and how do they affect well-being? Econ Labour Relat Rev. 2017;28(3):402-19. https://doi.org/10.1177/1035304617722943.
20. Julia M, Vanroelen C, Bosmans K, Van Aerden K, Benach J. Precarious Employment and Quality of Employment in Relation to Health and Well-being in Europe. Int J Health Serv. 2017;47(3):389-409. https://doi.org/ 10.1177/0020731417707491.
21. Benavides FG, Benach J, Diez-Roux AV, Roman C. How do types of employment relate to health indicators? Findings from the second European survey on working conditions. J Epidemiol Community Health. 2000;54(7):494-501. https:// doi.org/10.1136/jech.54.7.494.
22. Puig-Barrachina V, Vanroelen C, Vives A, Martínez JM, Muntaner C, Levecque K et al. Measuring employment precariousness in the European Working Conditions Survey: the social distribution in Europe. Work. 2014;49(1):143-61.
23. Julia M, Belvis F, Vives A, Tarafa G, Benach J. Informal employees in the European Union: working conditions, employment precariousness and health. J Public Health (Oxf). 2019;41(2):e141-e151. https://doi.org/10.1093/ pubmed/fdy111.
24. Kretsos L, Livanos I. The extent and determinants of precarious employment in Europe. Int J Manpow. 2016; 37(1):25-43. https://doi.org/10.1108/IJM-12-2014-0243.
25. Van Aerden K, Gadeyne S, Vanroelen C. Is any job better than no job at all? Studying the relations between employment types, unemployment and subjective health in Belgium. Arch Public Health. 2017;75(1):55. https://doi. org/10.1186/s13690-017-0225-5.
26. Peckham T, Fujishiro K, Hajat A, Flaherty BP, Seixas N. Evaluating Employment Quality as a Determinant of Health in a Changing Labor Market. RSF. 2019;5(4):258-81. https://doi.org/10.7758/rsf.2019.5A09.
27. Scott-Marshall H, Tompa E. The health consequences of precarious employment experiences. Work. 2011 ;38(4):369-82.
28. Canivet C, Bodin T, Emmelin M, Toivanen S, Moghaddassi M, Östergren PO. Precarious employment is a risk factor for poor mental health in young individuals in Sweden: a cohort study with multiple follow-ups. BMC Public Health. 2016; 16(1):687. https://doi.org/10.1186/s12889-016-3358-5.
29. Rönnblad T, Grönholm E, Jonsson J, Koranyi I, Orellana C, Kreshpaj B et al. Precarious employment and mental health: a systematic review and meta-analysis of longitudinal studies. Scand J Work Environ Health. 2019;45(5):429-43. https://doi.org/10.5271/sjweh.3797.
30. Duran X, Martínez JM, Benavides FG. Occupational factors associated with the potential years of working life lost due to a non-work related permanent disability. Work. 2013;45(3):305-9.
31. Hougaard CO, Nygaard E, Holm AL, Thielen K, Diderichsen F. Job mobility and health in the Danish workforce. Scand J Public Health. 2017;45(1):57-63. https://doi.org/10.1177/1403494816680785.
32. Virtanen M, Kivimäki M, Ferrie JE, Elovainio M, Honkonen T, Pentti J et al. Temporary employment and antidepressant medication: a register linkage study. J Psychiatr Res. 2008;42(3):221-9. https://doi.org/10.1016/j. jpsychires.2006.12.005.
33. Ervasti J, Vahtera J, Virtanen P, Pentti J, Oksanen T, Ahola K et al. Is temporary employment a risk factor for work disability due to depressive disorders and delayed return to work? The Finnish Public Sector Study. Scand J Work Environ Health. 2014;40(4):343-52. https://doi.org/10.5271/sjweh.3424.
34. Zaballa E, Martínez JM, Duran X, Alberti C, Gimeno Ruiz de Porras D, Benavides FG. Incidence of sickness absence by type of employment contract: one year followup study in Spanish salaried workers. Arch Public Healt.h 2016;74(1):40. https://doi.org/10.1186/s13690-016-0152-x.
35. Sparke M. Introducing globalization: The ties that bind. Chichester, UK: Wiley-Blackwell; 2013.
36. Vives A, Vanroelen C, Amable M, Ferrer M, Moncada S, Llorens C, et al. Employment precariousness in Spain: prevalence, social distribution, and population-attributable risk percent of poor mental health. Int J Health Serv.

2011;41(4):625-46.
37. Koranyi I, Jonsson J, Rönnblad T, Stockfelt L, Bodin T. Precarious employment and occupational accidents and injuries - a systematic review. Scand J Work Environ Health. 2018;44(4):341-50. https://doi.org/10.5271/sjweh.3720.
38. Jung Y, Oh J, Huh S, Kawachi I. The effects of employment conditions on smoking status and smoking intensity: the analysis of Korean labor &income panel 8(th)-10(th) wave. PLoS One. 2013;8(2):e57109. https://doi.org/10.1371/ journal.pone.0057109.
39. Min JY, Park SG, Hwang SH, Min KB. Disparities in precarious workers' health care access in South Korea. Am J Ind Med. 2016;59(12):1136-44. https://doi.org/10.1002/ ajim.22658.
40. Steele EJ, Giles LC, Davies MJ, Moore VM. Is precarious employment associated with women remaining childless until age 35 years? Results from an Australian birth cohort study. Hum Reprod. 2014;29(1):155-60. https://doi. org/10.1093/humrep/det407.
41. Ojala S, Pyöriä P. Precarious work and the risk of receiving a disability pension. Scand J Public Health. 2019;47(3):293300. https://doi.org/10.1177/1403494818804106.
42. Benach J, Vives A, Tarafa G, Delclos C, Muntaner C. What should we know about precarious employment and health in 2025? Framing the agenda for the next decade of research. Int J Epidemiol. 2016;45(1):232-8. https://doi.org/10.1093/ ije/dyv342.
43. Muntaner C, Solar O, Vanroelen C, Martinez JM, Vergara M, Santana V, et al. Unemployment, informal work, precarious employment, child labor, slavery, and health inequalities: pathways and mechanisms. Int J Health Serv. 2010;40(2):281-95.
44. Wagenaar AF, Kompier MA, Houtman IL, van den Bossche SN, Taris TW. Employment contracts and health selection: unhealthy employees out and healthy employees in? J Occup Environ Med. 2012;54(10):1192-200. https://doi. org/10.1097/JOM.0b013e3182717633.
45. Hunefeld L, Koper B. Fixed-term Employment and Job Insecurity (JI) as Risk factors for Mental Health. A Review of International Study Results. E-J Int Comp Labour. 2016;5:1-22.
46. Benach J, Muntaner C, Benavides FG, Amable M, Jodar P. A new occupational health agenda for a new work environment. Scand J Work Environ Health. 2002;28(3):191-6. https://doi.org/10.5271/sjweh.664.
47. Van Aerden K, Moors G, Levecque K, Vanroelen C. Measuring Employment Arrangements in the European Labour Force: A Typological Approach. Soc Indic Res. 2014;116(3):771-91. https://doi.org/10.1007/s11205-0130312-0.
48. Matilla-Santander N, Lidón-Moyano C, González-Marrón A, Bunch K, Martín-Sánchez JC, Martínez-Sánchez JM. Measuring precarious employment in Europe 8 years into the global crisis J Public Health. 2019;41(2):259-67. https:// doi.org/10.1093/pubmed/fdy114.
49. U.S. Bureau of Labor Statistics. Contingent and Alternative Employment Arrangements Summary. U.S. Department of Labor; 2018 [cited 2019 2/26/2019]; Available from: https:// www.bls.gov/news.release/pdf/conemp.pdf.
50. Lee SS. High non-standard employment rates in the Republic of Korea and Japan: analyzing policy configurations with fuzzy-set/QCA. Policy Soc. 2013;32(4):333-44. https://doi. org/10.1016/j.polsoc.2013.10.005.
51. Abdul Karim S, Eikemo TA, Bambra C. Welfare state regimes and population health: integrating the East Asian welfare states. Health Policy. 2010;94(1):45-53. https://doi. org/10.1016/j.healthpol.2009.08.003.
52. Clement W, Mathieu S, Prus S, Uckardesler E. Precarious lives in the new economy: Comparative intersectional analysis. Gender and the contours of precarious employment: London, UK: Routledge; 2009. p240-55.
53. Menéndez M, Benach J, Muntaner C, Amable M, O'Campo P. Is precarious employment more damaging to women's health than men's? Soc Sci Med 2007 Feb;64(4):776-81. https://doi.org/10.1016/j.socscimed.2006.10.035.
54. Ansoleaga E, Díaz X, Mauro A. [Psychosocial risks, quality of employment, and workplace stress in Chilean wageearning workers: a gender perspective]. Cad Saude Publica. 2016;32(7).
55. OECD. International Migration Outlook: Annual Report. Paris: OECD Publishing; 2007.
56. Forde C, Slater G, Green F. Agency working in Britain: what do we know. Centre for Employment Relations

Innovation and Change Policy Report. 2008 (2).
57. McKay S. Trade unions and recent migration: organising challenges in an enlarged EU. WLRI Working Paper, 2008.
58. Waldinger R, Lichter MI. How the other half works: Immigration and the social organization of labor. Berkeley, CA: Univ of California Press; 2003.
59. Castles S, Kosack G. Immigrant workers and class structure in Western Europe. London, UK: Oxford University Press; 1973.
60. Vosko LF. Managing the margins: Gender, citizenship, and the international regulation of precarious employment. London, UK: Oxford University Press; 2010.
61. Olsthoorn M. Measuring Precarious Employment: A Proposal for Two Indicators of Precarious Employment Based on SetTheory and Tested with Dutch Labor Market-Data. Soc Indic Res. 2014;119(1):421-41. https://doi.org/10.1007/s11205013-0480-y.
Received for publication: 28 August 2019

DETAILS

Subject:	Temporal resolution; Public health; Immigrants; Working conditions; Occupational health; Health disparities; Researchers; Wages &salaries; Exposure; Working groups; Quality; Employment; Studies; Medical research; Construction standards
Location:	Turkey; Sweden; United States--US; Belgium
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	321-329,321A
Publication year:	2020
Publication date:	2020
Section:	Discussion paper
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal

Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3860
ProQuest document ID:	2406985214
Document URL:	https://www.proquest.com/scholarly-journals/precarious-employment-occupational-health-omega/docview/2406985214/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2020-05-27
Database:	Public Health Database

Influence of errors in job codes on job exposure matrix-based exposure assessment in the register-based occupational cohort DOC*X

Petersen, S B [1] ; Flachs, E M; Svendsen, S W; Marott, J L; Budtz-Jørgensen, E; Hansen, J; Stokholm, Z A; Schlünssen, V; Andersen, J H; Bonde, J P [1] Department of Occupational and Environmental Medicine, Bispebjerg and Frederiksberg Hospital, University of Copenhagen, Copenhagen, Denmark

ABSTRACT (ENGLISH)

Objective Job-exposure matrices (JEM) may be efficient for exposure assessment in occupational epidemiological studies, but they rely on valid job information. We evaluated the agreement between JEM-based exposure estimates according to self-reported job titles converted to DISCO-88 codes and according to register-based DISCO-88 codes in the Danish Occupational Cohort with eXposure data (DOC·X). Furthermore, we evaluated the agreement between these two sets of DISCO-88 codes.
Methods We used JEM regarding wood dust, lifting, standing/walking, arm elevation >90°, and noise from DOC·X. Participants from previous questionnaire studies were assigned JEM-based exposure estimates using (i) self-reported job titles converted to DISCO-88 codes and (ii) DISCO-88 codes registered in DOC·X, in four time periods (1976-78: N=7707; 1981-83: N=2193; 1991-94: N=2664; 2004: N=11 782). Agreement between the exposure estimates and between the DISCO-88 codes (four-digit levels, 1-4) was evaluated by kappa (κ) statistics. Sensitivities were calculated using the self-reported observation as the gold standard.
Results We found substantial agreement (κ>0.60) between exposure estimates for all types of job-exposures and all time periods except for one κ. Low sensitivity (30-65%) was found for the period 1981-83, but for the other time periods the sensitivities varied between 60-91%. For individual 4-digit DISCO-88 codes, the sensitivities varied substantially and overall the sensitivities increased by lower digit level of DISCO-88.
Conclusion The validity of the DISCO-88 codes in DOC·X was generally high. Substantial agreement was found for

the JEM-based exposure estimates and the DISCO-88 codes per se, although the DISCO-88 codespecific agreement varied across digit levels and time periods.

FULL TEXT

Headnote

Objective Job-exposure matrices (JEM) may be efficient for exposure assessment in occupational epidemiological studies, but they rely on valid job information. We evaluated the agreement between JEM-based exposure estimates according to self-reported job titles converted to DISCO-88 codes and according to register-based DISCO-88 codes in the Danish Occupational Cohort with eXposure data (DOC·X). Furthermore, we evaluated the agreement between these two sets of DISCO-88 codes.

Methods We used JEM regarding wood dust, lifting, standing/walking, arm elevation >90°, and noise from DOC·X. Participants from previous questionnaire studies were assigned JEM-based exposure estimates using (i) self-reported job titles converted to DISCO-88 codes and (ii) DISCO-88 codes registered in DOC·X, in four time periods (1976-78: N=7707; 1981-83: N=2193; 1991-94: N=2664; 2004: N=11 782). Agreement between the exposure estimates and between the DISCO-88 codes (four-digit levels, 1-4) was evaluated by kappa (κ) statistics. Sensitivities were calculated using the self-reported observation as the gold standard.

Results We found substantial agreement (κ>0.60) between exposure estimates for all types of job-exposures and all time periods except for one κ. Low sensitivity (30-65%) was found for the period 1981-83, but for the other time periods the sensitivities varied between 60-91%. For individual 4-digit DISCO-88 codes, the sensitivities varied substantially and overall the sensitivities increased by lower digit level of DISCO-88.

Conclusion The validity of the DISCO-88 codes in DOC·X was generally high. Substantial agreement was found for the JEM-based exposure estimates and the DISCO-88 codes per se, although the DISCO-88 codespecific agreement varied across digit levels and time periods.

Key terms arm elevation; epidemiology; ISCO-88; JEM; job code error; lifting; metal dust; noise; occupation; shoulder; standing; validity; walking; wood dust.

Since the late 1970s, job-exposure matrices (JEM) have been increasingly used to obtain exposure estimates in occupational epidemiological studies. A JEM is a cross-tabulation of job titles or occupational codes and occupational exposures, preferably for a specific time window (1-4). JEM can be used in large epidemiological studies where methods based on individual interview data, observation, or technical measurements would be very costly. Other important advantages are that JEM can be used to estimate both current and past exposures and minimize the risk of information bias compared to individual-based self-report methods (2, 5, 6).

The validity of occupational exposure estimates assigned to individuals by means of JEM depends on the quality of information about exposures in specific jobs in different time periods, as well as on correct job titles or occupational codes (7). The latter aspect of JEM validity is particularly important when occupational codes are retrieved from national registers, without occupational research as the primary objective. While the validity of exposures assigned by JEM has been examined in a number of publications (8-13), the validity of the job titles and occupational codes per se has seldom been examined (7, 14). Incorrect occupational codes in registers may be the result of erroneous reporting from the primary sources (eg, tax agents, companies) and - if classification systems have changed over time - errors in translation from one classification system to another. Therefore, the validity of registered occupational codes may vary between industries and occupations and across time periods.

The Danish Occupational Cohort with exposure data (DOC·X) is a nationwide cohort for occupational research containing occupational histories in terms of year-by-year codes according to the Danish version of the International Standard Classification of Occupations (DISCO) on an individual level from 1970 through 2015 with ongoing updates. DOC·X is an open research resource that provides opportunities to perform registerbased epidemiological studies of occupational exposures by use of JEM (15). The validity of the DISCO codes in the nationwide registers, which form the foundation of DOC·X, has not been investigated.

The overall aim of this study was to evaluate the validity of DISCO codes in DOC·X. Specific aims were to evaluate

(i) the agreement between JEM-based exposure estimates according to self-reported job titles converted to DISCO codes and according to registerbased DISCO codes in DOC·X; and (ii) the agreement between these two sets of DISCO codes per se.

Methods

Danish Occupational Cohort with exposure data (DOC·X)

DOC·X is a nationwide database including 6.4 million residents in Denmark from the age of 16, who have been gainfully employed at a private or public workplace in Denmark from 1970 through 2015 (15-17). The database has been compiled and is updated at a secured platform at Statistics Denmark. The backbone of the database is the information on occupation and industry, which includes calendar specific DISCO-88 codes for each individual based on the 1970 Census (16) and the Employment Classification Module (1976-2015) (17). The Employment Classification Module has used three classifications: (i) a scheme developed by Statistics Denmark based on ISCO-68 (1976-1990), (ii) DISCO-88 (1991-2009), and (ii) DISCO-08 (2010 onwards) (15). In DOC·X, the different coding versions have been harmonized to DISCO-88 codes in a code-by-code manner as described previously (15). The codes vary in detail from 1- to 4-digit levels, of which the last-mentioned is the most detailed. The annual DISCO-88 code for each individual is defined by the job with the highest income during each calendar year. We extracted annual DISCO88 codes by use of the personal identifier (18).

Population used for validation

From 1976-1994, we used occupational data from the Copenhagen City Heart Study (CCHS). In total, 19 698 men and women from the center of Copenhagen were randomly drawn from the Copenhagen Population Register. The sample was age-stratified within 5-year age groups from 35-70 years of age. All participants completed a self-administrated questionnaire in 1976-1978, including a freeform question about current job title (N=14 223). Follow-up studies with information on job title were completed in 1981-83 (>500 20-25-year-olds) and in 1991-94 (>3000 20-49 year-olds) (19, 20). The proportions that responded were 73.6% at baseline and 70.2% and 61.2% at follow-up. In the beginning of 2016, the job title text strings from the stored questionnaires were digitalized and assigned DISCO-88 codes by three librarians, who worked independently. The codes were cross-checked and a supervising occupational health specialist resolved discrepancies.

For 2004, we used data from the ASUSI cohort of 14 266 men and women, who completed a questionnaire in a population-based study of working environment and sickness absence (ASUSI is a Danish acronym for working environment, sickness absence, premature exit from the labor market, social inheritance, and intervention) (21). Two trained sociologists digitalized the job title text strings from the questionnaires assigned DISCO-88 codes. Only persons who had been in employment for >80% of the time during the previous year or had been employed for 6 out of the 12 weeks preceding 1 July 2004 were included.

Assessment of occupational exposure intensities

We assessed five types of exposure using four JEM:

Wood dust estimates were assessed using a wood dust JEM based on expert ratings and 12 704 measurements collected in 1978-2007 in wood related industries in six European countries (22, 23). We dichotomized the exposures as non-exposed and exposed because wood dust exposure was rare in the study population.

Lifting and standing/walking estimates were assessed using the Lower Body JEM (24) . Five Danish occupational health physicians with a minimum of 10 years of experience rated the exposures. We categorized the lifting exposures as described previously (25-28) (0=nonexposed, 1=medium exposed (>0-<1000 kg/day), and 2=highly exposed (>1000 kg/day)) and divided the exposure estimates for standing/walking into three groups [(0=non-exposed (0 hours/day), 1=medium exposed (>0-5.9 hours/day), and 2=highly exposed (>6.0 hours/ day)] according to previously used categories (27, 28).

Work with the arms elevated >90° estimates were assessed using the Shoulder JEM, which is based on expert ratings by five Danish occupational health physicians with a minimum of 10 years of experience (29-32). The expert rated estimates of time spent working with the arms elevated >90° (hours/day) have been validated against technical measurements (13). We divided the exposure estimates according to previously used cut-off value for high exposure

(0=non-exposed, 1=medium exposed (>0-0.4 hours/day), and 2=highly exposed (>0.5 hours/day) (32, 33).
Noise was assessed using the Noise JEM (35, 36), which is based on personal dosimeter measures of occupational noise exposure in the periods 2001-03 and 2009-10 among 1140 workers (1343 measurements) within the ten industries with the highest reporting of noise induced hearing loss according to the Danish Working Environment Authority. The measurements represented 100 occupational titles according to the DISCO-88 system. Four experts rated the noise intensity levels for the remaining jobs using 35 benchmark groups. Their ratings were used to construct an expert score dependent on sex, age, and calendar time (34, 35). We used the categorical variable for noise exposure (0=<80 dB, 1=80-84 dB, 2=>85dB), based on ISO-1999 thresholds (35, 36).
We assigned exposure estimates to individuals in the CCHS/ASUSI cohorts with DISCO-88 codes for which a JEM exposure estimate was available. The estimates were assigned by connecting the JEM with their calendar-year specific DISCO-88 codes based on self-report and their DISCO-88 codes in DOC·X for the specific calendar year.
Statistical methods
From both cohorts (CCHS and ASUSI) and each time period, we excluded persons, who stated that they were unemployed or had retired. For each exposure and time period, the final population included only individuals with both sets of DISCO-88 codes and only DISCO-88 codes with >10 self-reported observations (37). Furthermore, we only included observations where JEM-based exposure estimates were available for both sets of codes.
We computed kappa coefficients (κ) with 95% confidence intervals (CI) for exposures with two exposure categories (wood dust) and weighted κ with 95% CI for exposures with three exposure categories (all other exposures). Additionally, we in 3x3 tables computed sensitivity (the percentage of true exposure categorizations for the highest exposed individuals) and specificity (the percentage of true exposure categorizations for the non-exposed individuals) based on self-report as the gold standard. This means that the medium exposed groups not were included in the interpretation of sensitivity and specificity. We also assessed the sensitivity and agreement (weighted κ) between the DISCO-88 codes per se (specificity was not assessed because it would always be very high due to the low frequency of persons in any DISCO-88 group compared to the total number of persons in the study). Sensitivity was calculated as the percentage of true registrations within each DISCO-88 code digit level (1-4) taking the DISCO-88 codes based on selfreport as the gold standard. In addition to the agreement at 1-, 2-, 3-, and 4-digit levels, we computed weighted κ coefficients by time period (1976-78; 1981-1983; 19911994; 2004) at DISCO-88 1-digit level (DISCO-88 major groups). We interpreted the κ coefficients as:<0=poor, 0.00-0.20=slight, 0.21-0.40=fair, 0.41-0.60=moderate, 0.61-0.80=substantial, and 0.81-1.00=almost perfect agreement (38). SAS software, version 9.4, (SAS Institute Inc, Cary, NC, USA) was used.
Results
Table 1 presents the number of DISCO-88 codes according to time period, including all digit levels of DISCO88 (based on self-reported job titles), that met the inclusion criteria of minimum ten observations in our final study dataset. These codes represented 29-56% of the total number of codes, including all digit levels of the DISCO-88 system, with the lowest percentage in 1991-94 and the highest in 2004. The number of individuals in each time period is also shown; their distribution across DISCO-88 groups is presented in supplementary table S1, www.sjweh.fi/show_abstract. php?abstract_id=3857.
As seen in table 2, our data showed substantial agreement between JEM-based exposure estimates according to the two sets of DISCO-88 codes based on self-reported job titles and registrations in DOC·X, except for noise in 1981-83. Across time, both the sensitivities and κ estimates were lowest for the time period 1981-83. Overall, the specificities were high showing substantial agreement for the non-exposed individuals. Table 3 shows that the agreements between the two sets of DISCO-88 codes were substantial across 1-, 2-, 3-, and 4-digit levels. The highest κ estimates were seen for the 4-digit DISCO-88 group level with estimates between 0.73-0.81. The sensitivities varied between 51.5-73.2% and were highest for the 1-digit DISCO-88 level. As seen in table 4, the DISCO-88 code specific agreement at 1-digit level varied from fair to almost perfect across time periods (κ=0.34-0.91). Group 0 (armed forces) had almost perfect agreement, whereas group 1 with legislators, senior officials, and managers showed the lowest agreement; no time trends were evident. The sensitivities generally showed the same

pattern as the κ-values.
Sensitivities for individual DISCO-88 codes, according to time period, are presented in supplementary table S1. The highest sensitivities across all time periods were found for dentists (2222; 96.2%); nursing associate professionals (3231; 95.0%); police officers (5162; 92.2%); medical doctors (2221; 91.5%); jewelry and preciousmetal workers (7313; 91.3%); bakers, pastry-cooks and confectionery-makers (7412; 89.3%); and primary education teaching professionals (2331; 89.8%). Prison guards (5163) and travel attendants (5111) and travel stewards had 100% sensitivity in 2004, but not enough observations for the other time periods. In general, low sensitivities were found across all time periods for business services agents and trade brokers not elsewhere classified (3429; 1.7%); production clerks (4132; 6.2%); other teaching associate professionals (3340; 6.5%); advertising and public relations managers (1234; 7.4%); finance and sales associate professionals not elsewhere classified (3419; 10.1%); safety, health and quality inspectors (11.7%; 3152); receptionists and information clerks (4222; 12.3%); and buyers (3416; 13.5%).
Discussion
Job titles and occupational codes constitute a crucial basis for the use of JEM, but errors in job titles and assignment of occupational codes have received minimal scientific attention. The present study benefitted from exposure data from JEM concerning five airborne, mechanical, and physical exposures. Self-reported job titles for the CCHS/ASUSI cohorts were translated into DISCO-88 codes, which were connected with the JEM to provide exposure estimates, which were then compared to JEM-based exposure estimates according to DISCO-88 codes registered in DOC·X. High sensitivities and substantial agreement was found for the JEMbased exposure estimates and for the DISCO-88 codes per se, although the DISCO-88 code-specific agreement varied across digit levels and across time periods.
The number of individuals in the study population from 1991-94 was low since only about one third of the individuals with a self-reported job title had a DISCO88 code in DOC·X. An explanation may be the higher mean age in the population by calendar time as the main part of the population was included in 1976 with an age of up to 70 years at that time. For example, if they retired from the workforce before 1991, they have no DISCO code registered in DOC·X database for the time-period 1991-94. The classification system used by Statistics Denmark changed in 1981 and 1993, which may be an explanation for lower agreement observed in the period 1981-83, and again in 1991-94. In 1981-83, the classification system was less detailed than the DISCO-88 system. This means that it was very difficult to translate specific job groups from that time-period to DISCO-88 codes. Therefore, discrepancies between DISCO-88 codes may be because of translation difficulties rather than exact differences between jobs. Because of the less detailed job groups in 1981-83, the solution was to translate job titles to less detailed DISCO-88 group levels. The system for code assignment also changed in 1991, when the DISCO-88 classification system was introduced by Statistics Denmark. The DISCO-88 was based on the ISCO-88. Before 1991, the occupational codes were assigned by trained coders at Statistics Denmark based on self-reported information and union membership, but from 1991 the system was automatized and based on tax records and other personal register information. This shift in code assignment led to a temporary reduction of data reporting, which probably also contributed to the low number of individuals in the final study population for 1991-94.
The variation across DISCO-88 codes probably reflected variations in the accuracy by which DISCO codes are reported to the central authorities. Reporting to Statistics Denmark from large public and private com- panies is undertaken by trained staff according to written guidelines, while small private companies with fewer resources may provide less accurate DISCO codes. It is only mandatory for Danish companies with >10 employees to report information on occupation, and therefore significant differences in accuracy may be expected.
The misclassification of JEM-based individual exposures assigned by using DISCO-88 codes in DOC·X seems less than might be expected based on comparison of the sensitivities for the DISCO-88 codes per se; overall, the sensitivities were higher when comparing JEM-based exposure estimates than when comparing the two sets of DISCO-88 codes (especially at the 3- and 4-digit levels). This is because DISCO-88 codes belonging to similar job groups in the JEM are assigned similar job-exposures (7, 14). For example, the noise JEM will assign the same low

level of noise exposure to all types of office workers regardless of the specific DISCO-88 code. Lack of agreement between two sets of DISCO-88 codes will therefore not necessarily affect the agreement between JEM-based exposure estimates.

The variation in agreement between the two sets of individual DISCO-88 codes seems to depend on characteristics of the jobs covered by the code. In general, the codes with lowest sensitivities are broadly defined and not specified, eg, business services agents and trade brokers not elsewhere classified, other teaching associate professionals, and finance and sales associate professionals not elsewhere classified. The two last-mentioned groups will probably be classified as other kinds of office workers, which will reduce the effect of the misclassification on the assigned JEM-based exposure estimates (see above). Another possibility is to exclude DISCO codes with low sensitivities in epidemiological studies (at least in sensitivity analyses) as they may increase the risk of misclassification of exposures. Thus, the actual validity of the DISCO-codes per se may be significantly higher in cleaned data prepared for analysis.

Strengths and limitations

One strength of our study is that we have data from four different time periods during a 24-year long period where Statistics Denmark used different classification systems of occupations in their registers. Furthermore, we have access to self-reported job titles. It may be questioned if self-reported job titles converted to DISCO-88 codes can be taken as a gold standard, but self-reported information on the current job is generally considered to have high validity (14, 39).

One limitation of our study is that we have no selfreported job titles from the years after 2004, and therefore no validation has been performed on DOC·X registrations from 2005 onwards. This limitation particularly pertains to DISCO-88 codes after the time point when Statistics Denmark introduced the DISCO-08 system in 2010 (15). Another limitation is that the DISCO-88 codes, which were available for validation, only represented around half of the codes in the DISCO-88 system so that only frequent occupational titles were validated at the 4-digit level. If the agreements are lower for rare DISCO88 codes, we may have overestimated the general validity of the DISCO-88 codes in DOC·X. On the other hand, the sensitivities did not seem to depend on the number of observations (all >10) per DISCO-code.

In our analyses of agreement between exposure levels, we used categorical variables with two or three categories. The JEM exposures for wood dust and noise only exist as categorical variables while the other JEM contain continuous measures, which we categorized to ensure comparability. It may be a limitation that we only validated the DISCO-88 codes based on categorical variables instead of using continuous scales. We chose to focus on the lowest and highest exposure categories to examine whether they were correctly categorized. To the extent that DISCO-88 codes in DOC·X are misclassified so that highly exposed are categorized as medium or non-exposed, the data would not be of a quality that allows future exposure-response analyses.

Validity of DISCO-88 codes in future DOC·X studies

This study concerned selected airborne, mechanical, and physical exposures, and it remains open whether the validity of DISCO-88 codes in DOC·X is similar for other exposures, eg, chemicals. The validity varied across 4-digit DISCO-88 codes and time periods, which should be considered when planning studies in DOC·X. DOC·X also covers industry codes from 1976 and onwards (15) and it can be relevant to use those industry codes together with the DISCO-88 codes to reduce the risk of misclassification of occupations.

Concluding remarks

The validity of the DISCO-88 codes in DOC·X was generally high. Substantial agreement was found for the JEM-based exposure estimates and group-based DISCO88 codes per se, although the DISCO-88 code-specific agreement varied across digit levels and time periods.

Funding

The Danish Working Environment Research Fund funded this study (grant no.: 43-2014-03 / 20140016763). The funding source played no role in the (i) study design, (ii) the collection, analysis and interpretation of the data, (iii) the writing of the report, or (iv) the decision to submit the paper for publication.

Conflicts of interest

The authors declare no conflicts of interest.

Sidebar

We found substantial agreement between job-exposure-matrix-derived exposure estimates according to DISCO-88 codes based on self-reported job-titles and registered in the Danish Occupational Cohort with exposure data (DOC·X), with respect to airborne, mechanical, and physical exposures. Substantial agreement was also found between the two sets of DISCO-88 codes. The results are promising with respect to future studies based on the DOC·X.

Refers to the following texts of the Journal: 2019;45(3):239-247 2013;39(6):568-577 2014;40(4):411-419 1993;19(1):21-28 2001;27(2):125-132

The following articles refer to this text: [online first; 20 January 2020]; 2020;46(3):231-234; [online _ first; 05 _ May'2020].

Key terms: arm elevation; DOC·X; epidemiology; exposure; ISCO-88; JEM; job code; job code error; job exposure matrix; lifting; metal dust; noise; occupation; occupational cohort ; shoulder; standing; validity; walking; wood dust

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31642934

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Petersen SB, Flachs EM, Svendsen SW, Marott JL, Budtz-Jørgensen E, Hansen J, Stokholm ZA, Schlünssen V, Andersen JH, Bonde JP. Influence of errors in job codes on job exposure matrix-based exposure assessment in the register-based occupational cohort DOC·X. Scand J Work Environ Health. 2020;46(3):259-267. doi:10.5271/sjweh.3857

Correspondence to: Sesilje Bondo Petersen, Department of Occupational and Environmental Medicine, Bispebjerg and Frederiksberg Hospital, University of Copenhagen, Copenhagen, Denmark. [E-mail: sesilje.elise.bondo.petersen@regionh.dk]

Footnote

1 Department of Occupational and Environmental Medicine, Bispebjerg and Frederiksberg Hospital, University of Copenhagen, Copenhagen, Denmark.

2 Danish Ramazzini Centre, Department of Occupational Medicine, Regional Hospital West Jutland - University Research Clinic, Herning, Denmark.

3 Copenhagen City Heart Study, Frederiksberg University Hospital, Copenhagen, Denmark.

4 Section of Biostatistics, Department of Public Health, University of Copenhagen, Copenhagen, Denmark

5 Danish Cancer Society Research Center, Copenhagen, Denmark.

6 Danish Ramazzini Centre, Department of Occupational Medicine, Aarhus University Hospital, Aarhus, Denmark.

7 National Research Centre for Working Environment, Copenhagen, Denmark.

8 Department of Public Health, Occupation, Environment and Health, Danish Ramazzini Centre, Aarhus University, Denmark.

References

References

1. Johnson JV, Stewart WF. Measuring work organization exposure over the life course with a job-exposure matrix. Scand J Work Environ Health 1993 Feb;19(1):21-8. https:// doi.org/10.5271/sjweh.1508.

2. Kauppinen T, Heikkilä P, Plato N, Woldbaek T, Lenvik K, Hansen J et al. Construction of job-exposure matrices for the Nordic Occupational Cancer Study (NOCCA). Acta Oncol 2009;48(5):791-800. https://doi. org/10.1080/02841860902718747.

3. 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 Apr;58(3):380-96.

4. Kennedy SM, Le Moual N, Choudat D, Kauffmann F. Development of an asthma specific job exposure matrix and its application in the epidemiological study of genetics and environment in asthma (EGEA). Occup Environ Med 2000 Sep;57(9):635-41. https://doi.org/10.1136/oem.57.9.635.
5. Greenland S, Fischer HJ, Kheifets L. Methods to explore uncertainty and bias introduced by job exposure matrices. Risk Anal 2016 Jan;36(1):74-82. https://doi.org/10.1111/ risa.12438.
6. Kauppinen TP. Assessment of exposure in occupational epidemiology. Scand J Work Environ Health 1994;20(Spec No):19-29.
7. Mannetje A, Kromhout H. The use of occupation and industry classifications in general population studies. Int J Epidemiol 2003 Jun;32(3):419-28. https://doi.org/10.1093/ ije/dyg080.
8. Solovieva S, Pehkonen I, Kausto J, Miranda H, Shiri R, Kauppinen T et al. Development and validation of a job exposure matrix for physical risk factors in low back pain. PLoS One 2012;7(11):e48680. https://doi.org/10.1371/ journal.pone.0048680.
9. Sjöström M, Lewné M, Alderling M, Willix P, Berg P, Gustavsson P et al. A job-exposure matrix for occupational noise: development and validation. Ann Occup Hyg 2013 Jul;57(6):774-83.
10. Niedhammer I, Milner A, LaMontagne AD, Chastang JF. Study of the validity of a job-exposure matrix for the job strain model factors: an update and a study of changes over time. Int Arch Occup Environ Health 2018 Jul;91(5):523-36. https://doi.org/10.1007/s00420-018-1299-2.
11. Hanvold TN, Sterud T, Kristensen P, Mehlum IS. Mechanical and psychosocial work exposures: the construction and evaluation of a gender-specific job exposure matrix (JEM). Scand J Work Environ Health 2019 May;45(3):239-47. https://doi.org/10.5271/sjweh.3774.
12. Dale AM, Ekenga CC, Buckner-Petty S, Merlino L, Thiese MS, Bao S et al. Incident CTS in a large pooled cohort study: associations obtained by a Job Exposure Matrix versus associations obtained from observed exposures. Occup Environ Med 2018 Jul;75(7):501-6. https://doi.org/10.1136/ oemed-2017-104744.
13. Dalbøge A, Hansson GA, Frost P, Andersen JH, HeilskovHansen T, Svendsen SW. Upper arm elevation and repetitive shoulder movements: a general population job exposure matrix based on expert ratings and technical measurements. Occup Environ Med 2016 Aug;73(8):553-60. https://doi. org/10.1136/oemed-2015-103415.
14. Kromhout H, Vermeulen R. Application of job-exposure matrices in studies of the general population: some clues to their performance. Eur Respir Rev 2001;11:80-90.
15. Flachs EM, Petersen SB, Kolstad HA, Schlünssen V, Svendsen SW, Hansen J et al. Cohort Profile: DOC·X: a nationwide Danish Occupational Cohort with eXposure data - an open research resource. Int J Epidemiol 2019;dyz110. https://doi.org/10.1093/ije/dyz110.
16. Denmark S. Folke og Boligtæ llingen 1970 [Census 1970]. 2018.
17. Petersson F, Baadsgaard M, Thygesen LC. Danish registers on personal labour market affiliation. Scand J Public Health 2011 Jul;39(7 Suppl):95-8. https://doi. org/10.1177/1403494811408483.
18. Pedersen CB. The Danish Civil Registration System. Scand J Public Health 2011 Jul;39(7 Suppl):22-5. https://doi. org/10.1177/1403494810387965.
19. Appleyard M, Hansen A, Schnohr P, Jensen G, Nyboe J. The Copenhagen City Heart Study. Østerbroundersøgelsen. A book of tables with data from the first examination (19761978) and a 5-year follow-up (1981-83). Scand J Soc Med Suppl 1989;170:1-160.
20. Schnohr P, Jensen G, Lange P, Scharling H, Appleyard M. The Copenhagen City Heart Study. Eur Heart J Suppl 2001;3 Suppl H:H1-83. https://doi.org/10.1016/S1520765X(01)90110-5.
21. Hansen CD, Andersen JH. Going ill to work-what personal circumstances, attitudes and work-related factors are associated with sickness presenteeism? Soc Sci Med 2008 Sep;67(6):956-64. https://doi.org/10.1016/j. socscimed.2008.05.022.
22. Basinas I, Liukkonen T, Sigsgaard T, Andersen NT, Vestergaard JM, Galea K, et al. P096 Statistical modelling and development of a quantitative job exposure matrix for wood dust in the wood manufacturing industry. 2016;73(Suppl 1):A152-A3.

23. Basinas I, Wouters IM, Sigsgaard T, Heederik D, Spaan S, Smit LA, et al. O46-4 Development of a quantitative job exposure matrix for endotoxin exposure in agriculture. 2016;73(Suppl 1):A88-A.
24. Rubak TS, Svendsen SW, Andersen JH, Haahr JP, Kryger A, Jensen LD et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014 Jun;15:204. https://doi.org/10.1186/1471-247415-204.
25. Runge SB, Pedersen JK, Svendsen SW, Juhl M, Bonde JP, Nybo Andersen AM. Occupational lifting of heavy loads and preterm birth: a study within the Danish National Birth Cohort. Occup Environ Med 2013 Nov;70(11):782-8. https://doi.org/10.1136/oemed-2012-101173.
26. Juhl M, Larsen PS, Andersen PK, Svendsen SW, Bonde JP, Nybo Andersen AM et al. Occupational lifting during pregnancy and child's birth size in a large cohort study. Scand J Work Environ Health 2014 Jul;40(4):411-9. https://doi.org/10.5271/sjweh.3422.
27. Tabatabaeifar S, Frost P, Andersen JH, Jensen LD, Thomsen JF, Svendsen SW. Varicose veins in the lower extremities in relation to occupational mechanical exposures: a longitudinal study. Occup Environ Med 2015 May;72(5):330-7. https:// doi.org/10.1136/oemed-2014-102495.
28. Vad MV, Frost P, Rosenberg J, Andersen JH, Svendsen SW. Inguinal hernia repair among men in relation to occupational mechanical exposures and lifestyle factors: a longitudinal study. Occup Environ Med 2017 Nov;74(11):769-75. https://doi.org/10.1136/oemed-2016-104160.
29. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: a nationwide Danish cohort study. Occup Environ Med 2014 Nov;71(11):750-6. https://doi.org/10.1136/oemed-2014-102161.
30. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Surgery for subacromial impingement syndrome in relation to occupational exposures, lifestyle factors and diabetes mellitus: a nationwide nested case-control study. Occup Environ Med 2017 Oct;74(10):728-36. https://doi. org/10.1136/oemed-2016-104272.
31. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Surgery for subacromial impingement syndrome in relation to intensities of occupational mechanical exposures across 10-year exposure time windows. Occup Environ Med 2018 Mar;75(3):176-82. https://doi.org/10.1136/ oemed-2017-104511.
32. Svendsen SW, Dalbøge A, Andersen JH, Thomsen JF, Frost P. Risk of surgery for subacromial impingement syndrome in relation to neck-shoulder complaints and occupational biomechanical exposures: a longitudinal study. Scand J Work Environ Health 2013 Nov;39(6):568-77. https://doi. org/10.5271/sjweh.3374.
33. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: a nationwide Danish cohort study. Occup Environ Med 2014 Nov;71(11):750-6. https://doi.org/10.n36/oemed-2014-102161.
34. Kock S, Andersen T, Kolstad HA, Kofoed-Nielsen B, Wiesler F, Bonde JP. Surveillance of noise exposure in the Danish workplace: a baseline survey. Occup Environ Med 2004 Oct;61(10):838-43. https://doi.org/rn.1136/oem.2004.012757.
35. Stokholm ZA, Bonde JP, Christensen KL, Hansen AM, Kolstad HA. Occupational noise exposure and the risk of hypertension. Epidemiology 2013 Jan;24(1):135-42. https://doi.org/10.1097/EDE.0b013e31826b7f76.
36. Lutman ME. What is the risk of noise-induced hearing loss at 80, 85, 90 dB(A) and above? Occup Med (Lond) 2000 May;50(4):274-5. https://doi.org/10.1093/occmed/50.4.274.
37. Hoozemans MJ, Burdorf A, van der Beek AJ, Frings-Dresen MH, Mathiassen SE. Group-based measurement strategies in exposure assessment explored by bootstrapping. Scand J Work Environ Health 2001 Apr;27(2):125-32. https://doi. org/10.5271/sjweh.599.
38. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977 Mar;33(1):159-74. https://doi.org/10.2307/2529310.
39. Baumgarten M, Siemiatycki J, Gibbs GW. Validity of work histories obtained by interview for epidemiologic purposes. Am J Epidemiol 1983 Oct;118(4):583-91. https://doi. org/10.1093/oxfordjournals.aje.a113663.
40. Madsen IE, Gupta N, Budtz-Jørgensen E, Bonde JP, Framke E, Flachs EM et al. Physical work demands and

psychosocial working conditions as predictors of musculoskeletal pain: a cohort study comparing self-reported and job exposure matrix measurements. Occup Environ Med 2018 Oct;75(10):752-8. https://doi. org/10.1136/oemed-2018-105151.
41. Bondo Petersen S, Flachs EM, Prescott EI, Tjønneland A, Osler M, Andersen I et al. Job-exposure matrices addressing lifestyle to be applied in register-based occupational health studies. Occup Environ Med 2018 Dec;75(12):890-7. https://doi.org/10.1136/oemed-2018-104991.
Received for publication: 14 May 2019

DETAILS

Subject:	Agreements; Population; Epidemiology; Estimates; Questionnaires; Dust; Noise; Codes; Exposure; Calendars; Evaluation; Validity; Age; Classification; Occupations; Occupational exposure; Job titles; Occupational health; Employment; Levels
Business indexing term:	Subject: Job titles Occupational health Employment
Location:	Denmark
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	259-267,259A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article

DOI:	https://doi.org/10.5271/sjweh.3857
ProQuest document ID:	2406985141
Document URL:	https://www.proquest.com/scholarly-journals/influence-errors-job-codes-on-exposure-matrix/docview/2406985141/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2022-05-31
Database:	Public Health Database

Acute myocardial infarction in relation to physical activities at work: a nationwide follow-up study based on job-exposure matrices

Bonde, J P E [1] ; Flachs, E M; Madsen, I E H; Petersen, S B; Andersen, J H; Hansen, J; Jørgensen, B; Kolstad, H; Holtermann, A; Schlünssen, V; Svendsen, S W [1] Bispebjerg Frederiksberg Hospitals, Department of Occupational and Environmental Medicine, Bispebjerg Bakke 23, DK-Copenhagen 2400 NV, Denmark

ABSTRACT (ENGLISH)

Objective: This study aimed to evaluate sex-specific risks of acute myocardial infarction (AMI) according to lifting and standing/walking at work.

Methods The study population included 1.15 million Danish wage earners. Annual job codes from 1976 onwards were linked to specific exposures using job-exposure matrices (JEM). Cases of AMI during follow-up 1996-2016 were retrieved from national registers. Incidence rate ratios (IRR) were computed by Poisson regression adjusting for demographic and JEM-assessed lifestyle factors. Models addressed physical activities at work the previous 0-2 years (short-term risk) and cumulative physical activities (long-term risk).

Results During 21.4 million person-years of follow-up, 22 037 AMI occurred in men and 6942 in women. Exposure-response relationships between recent physical activities at work and AMI were not evident. In men, the fully adjusted long-term IRR for the highest of five exposure categories compared to the lowest were 1.09 [95% confidence interval (CI) 1.03-1.15] for lifting and 1.01 (95% CI 0.96-1.07) for standing/walking. In women, the corresponding figures were 1.27 (95% CI 1.15-1.40) and 1.18 (95% CI 1.07-1.30). The latter risk estimate was strongly attenuated, and the trend became insignificant when adjusted for lifting. Findings were only partially supported by sensitivity analyses.

Conclusion The study provides limited support to the hypothesis that long-term lifting and standing/walking at work is related to increased risk of AMI. Possible effects of acute physical exertion are not addressed and bias towards the null because of crude exposure assignment cannot be ruled out.

FULL TEXT

Headnote

Objective: This study aimed to evaluate sex-specific risks of acute myocardial infarction (AMI) according to lifting and standing/walking at work.

Methods The study population included 1.15 million Danish wage earners. Annual job codes from 1976 onwards were linked to specific exposures using job-exposure matrices (JEM). Cases of AMI during follow-up 1996-2016 were retrieved from national registers. Incidence rate ratios (IRR) were computed by Poisson regression adjusting for demographic and JEM-assessed lifestyle factors. Models addressed physical activities at work the previous 0-2 years (short-term risk) and cumulative physical activities (long-term risk).

Results During 21.4 million person-years of follow-up, 22 037 AMI occurred in men and 6942 in women. Exposure-response relationships between recent physical activities at work and AMI were not evident. In men, the fully adjusted long-term IRR for the highest of five exposure categories compared to the lowest were 1.09 [95% confidence interval (CI) 1.03-1.15] for lifting and 1.01 (95% CI 0.96-1.07) for standing/walking. In women, the corresponding figures were 1.27 (95% CI 1.15-1.40) and 1.18 (95% CI 1.07-1.30). The latter risk estimate was strongly attenuated, and the trend became insignificant when adjusted for lifting. Findings were only partially supported by sensitivity analyses.

Conclusion The study provides limited support to the hypothesis that long-term lifting and standing/walking at work is related to increased risk of AMI. Possible effects of acute physical exertion are not addressed and bias towards the null because of crude exposure assignment cannot be ruled out.

There is strong epidemiological evidence that leisuretime physical activity is related to reduced cardiovascular morbidity and mortality (1-3). The lower threshold for beneficial effects seems to be less than moderateintensity physical activity, such as brisk walking (4). The US Department of Health and Human Services recommends >150 minutes a week of moderate-intensity aerobic physical activity or 75 minutes a week of vigorous-intensity physical activity (5). The seminal epidemiological studies of bus drivers and longshoremen from the 1950s and 60s indicate that physical activities at work are also beneficial for cardiovascular health (6-8). On the other hand, more recent studies have reported increased risk of ischaemic heart disease (IHD, atherosclerosis of the coronary arteries, the most prevalent type of cardiovascular morbidity) with increasing physical activities at work (9-14). Together with observations of increased all-cause mortality in studies addressing physically demanding work (15), the discrepancy between the beneficial effects of leisure1 time physical activity (LTPA) and the seemingly unfavourable effects of physical activities at work has been labelled a paradox (16, 17). However, studies often combine different physical activities at work such as walking, lifting, carrying, climbing stairs, and digging (18-21), even though relations with IHD may differ across activities (16). Thus, the evidence on effects of physical activities at work is far from clear.

In most studies of physical activities at work, exposure assessment is based on self-report, which may result in inflated risk estimates due to recall bias or deflated risk estimates because of inaccurate and crude assessment of exposure. Vaguely defined physical activities and potential confounding by social and lifestyle factors have been emphasized as major limitations (17). Other issues are small study populations, low participation, short followup time, limited exposure contrast and selective reporting.

Some of the methodological limitations of most earlier studies may be addressed by use of job-exposure matrices (JEM) in nationwide register-based studies, even though this approach may introduce other limitations such as exposure misclassification and challenges in obtaining information on potential confounders - information which is available in some recent large prospective studies (15, 22). JEM provide individual exposure measures in a transparent and independent way and can be applied in large populations with time specific information on occupation (23). Recently, lifestyle JEM have also been introduced (24, 25). Besides being time- and cost-effective, JEM may in some situations provide less attenuated risk estimates than individual-based exposure assessment (26).

Men and women share established risk factors for IHD (27) and therefore major sex-specific effects of physical activities at work are not expected. Nevertheless, analyses stratified by sex are justified to evaluate the consistency of findings. Acute myocardial infarction (AMI) is a prevalent manifestation of IHD with well-defined diagnostic criteria

and was selected for this study to ensure high specificity of the outcome.
The aim of this study was to evaluate the hypothesis that the sex-specific incidence rate of AMI is increased by short-term and long-term (cumulative) exposure to higher levels of physical activities at work in terms of lifting and standing/walking. These activities were chosen to include generic occupational activities of physically demanding and less-demanding nature.

Methods

Design and population

We conducted a follow-up study of all Danish residents, who in 1995 at an age of 31-50 years were gainful wage earners with a valid job code according to the Danish version of the International Standard Classification of Occupations from 1988 (DISCO-88) (28). We requested a DISCO-88 code at baseline in 1995 at the digit 2 level or higher. Military employees were excluded. The study population was retrieved as a subset of the Danish Occupational Cohort with exposure data (DOC·X) after permission from the Danish Data Protection Agency (P-2019-04) and from Statistics Denmark (P-707006). DOC·X is profiled in a separate paper (29).

Assessment of physical activities at work 1976-2015

Annual job codes. The DISCO-88 codes in the DOC·X are based on the Employment Classification Module (30, 31). These data mainly stem from public and private companies but are also retrieved from tax authorities and unemployment insurance funds. Various classification systems of occupational titles have been used within the past decades. In the DOC·X, occupational codes according to other classification systems than DISCO-88 have been converted to DISCO-88 codes (29), which have been validated against self-reported information on job titles (32).
Expert-rated JEM on lifting. To obtain estimates of occupational lifting, we used The Lower Body JEM (33), which provides estimates of total load lifted (kg/day) at work. This JEM has documented predictive validity for several outcomes (34-37). The JEM was constructed by grouping 2227 occupational titles into 122 job groups that were considered homogeneous with respect to physical activities at work (121 exposed groups and 1 minimally exposed group). Five experts in occupational medicine independently assessed the average total load lifted per day. If the most detailed DISCO-88 code included occupational titles from different job groups, the average exposure was used with few exceptions (38). In Denmark, specialists in occupational medicine have vast experience in quantifying total load lifted during a working day in all types of occupations because compensation for low back disorders and hip osteoarthritis is based upon detailed documentation of lifting work. The mean weighted kappa statistic for interrater agreement on ranking of the 121 job groups was 0.49 (moderate agreement (32). With few exceptions, two external experts confirmed the face validity of the rankings of the mean values (32). Furthermore, the average score on time spent lifting obtained for 125 DISCO-88 codes among men and women in a population survey (39) was strongly predicted by ranking of job codes according the expert-rated JEM (supplementary material, www. sjweh.fi/show_abstract.php?abstract_id=3863, figure S1). The range across lowest and highest deciles of DISCO-88 codes was 80-2640 kg/day. The JEM is not sex- or age-specific.
Self-report JEM on standing/walking. To obtain sex- and age-specific exposure estimates for standing/walking, we used the Occupational Activity JEM (39), which provides a sum score for the time spent standing/ walking during a working day. Data was derived from a questionnaire survey encompassing a population sample of employees in Denmark in 2012 (the Work Environment and Health in Denmark study, N=26 165, response proportion 51.5%). The question was: "Do you stand or walk at work?" With the following six response categories: (i) never, (ii) rarely, (iii) about ¼of the time, (iv) about ½of the time, (v) about ¾of the time, and (vi) almost all the time. Each answer was assigned a score from 1 (lowest) to 6 (highest). Using best linear unbiased prediction modeling, sexand age-specific scores were computed for 168 of the 372 DISCO-88 codes, where the survey provided enough information. For the purpose of this study, we computed average scores at the 2- and 3-digit level for codes without 4-digit level information. The intraclass correlation coefficient (ICC) across all 168 DISCO-88 codes was 0.42 for men and 0.44 for women. The range across lowest and highest deciles of DISCO-88 codes was 2.7-5.2 score points.
Exposure assignment by job-exposure matrices. Calendar-year specific exposures were assigned to each cohort member by linking DISCO-88 codes for the longest held job in a year with the JEM. For lifting, we assigned

cumulative exposures corresponding to the pack-year concept of smoking. One ton-year was defined as lifting one ton per day for one year (38). For standing/walking, we assigned cumulative exposures by summing up the scores for each year. The cumulative exposures were calculated across calendar years from 1976 or age 20, whichever came first. If the DISCO-88 code was missing or indicated military employment in years with active employment status according to the Employment Classification Module (8.2%), we assigned the average individual exposure during the latest up to five years. If still missing, we assigned exposure estimates of zero. Years without employment were also assigned a zero value. The quantitative estimates of exposure intensities (kg/day and standing/walking score points) and cumulative exposures (ton-years and standing/walking sum scores) were categorized by the sex-specific 25th, 50th, 75th and 90th percentiles.

Outcome ascertainment

We excluded cohort members with any type of IHD before start of follow-up using data on hospital discharge diagnoses (ICD-8 codes 410 from 1977-1993; ICD-10 codes I21-I23 as principal diagnosis from 1994-2016) obtained from the Danish National Patient Register (31). The outcome in the follow-up period (1996-2016) only included the specific diagnosis of AMI (ICD-10 principal diagnosis I21) due to a high completeness of data and validity of hospital information on this disease. The positive predictive value of a first-time AMI diagnosis according to the Danish National Patient Register was 97% in a validation study using medical records as the gold standard (40). Data on prehospital deaths from AMI during follow-up was retrieved from the Danish Register of Causes of Death (40) and constituted 6.9% of all incident cases.

Covariates

From public registers hosted by Statistics Denmark, we obtained information on the following baseline variables (1995): sex (men/women) and highest education (primary, secondary, short tertiary, medium tertiary, long tertiary and missing) as well as the following annually measured time-varying variables: vital status (alive/ dead), emigration (yes/no), disappearance (yes/no), age (integers), cohabitation (yes/no/missing), employment status [employee, employer, no gainful employment (including unemployment, long-term sick leave, disability pension and voluntary early retirement)] and social position defined by DISCO-88 major codes (first digit: 1-2 managers and professionals, 3 technicians, 4-5 clerks, service and sales workers, 6-7 skilled workers, 8-9 unskilled workers) (28).

Time-varying individual proxies of lifestyle factors in terms of sex-, age- and period-specific probability of current smoking and estimates of body mass index (BMI) (kg/m2) and LTPA [score points low (1) to high (6)] were assigned by lifestyle JEM based on questionnaire information from several large random samples of the Danish population (24). Lifestyle exposures in years without employment and in years with missing DISCO-88 codes were assigned the individual average exposure during all previous years (10.9% and 8.2%, respectively).

Statistical analysis

We used Poisson regression to compute sex-specific incidence rate ratios (IRR) with 95% confidence intervals (CI) for the association between incident AMI and physical activities at work from start of follow-up 1 January 1996 until first-occurring incident AMI (including prehospital death from AMI), death of another cause, emigration, disappearance or end of follow-up 31 December 2016. P-values for monotonic trends across exposure categories were computed by assigning integer values 0-4 to exposure categories (excluding the missing category) and reported if $P<0.001$ or <0.05 (subset analyses). Data on education was missing in 19% of records. Missings were kept as a separate category in the analyses.

Short-term risk. We analyzed the incidence of AMI according to physical activities at work the previous calendar year. Since employment status could not be resolved in more detail than one year, the one-year time lag spanned one day and two years.

Long-term risk. We analyzed the incidence of AMI according to cumulative physical activities at work from 1976 until and including the previous year.

Adjustments. All models were adjusted by a fixed set of constant and time-varying covariates. The constant covariates included sex (by stratification) and highest education at baseline (6 levels including a category of missing). The time varying variables were age (integers), cohabitation (yes/no/missing), social position (DISCO-88

major groups, 6 levels including a category of missing), employment status (employee, employer, no gainful employment), smoking (25th, 50th, 75th and 90th percentiles), BMI (25th, 50th, 75th and 90th percentiles) and LTPA (25th, 50th, 75th and 90th percentiles). The grouping of the three lifestyle variables were based upon cumulative years with a probability above the upper quartile. All timevarying variables were analyzed with a one-year time lag.
Sensitivity analyses. First, to counteract potential attenuation of risk estimates by the correlation between number of exposed years and staying in employment because of good health (healthy worker survivor selection), we repeated the analysis of long-term risk but redefined cumulative exposure as exposure from 1976 until but not including 1996 (start of follow-up) and ignored exposure during subsequent years. Second, we performed analyses according to cumulative exposures during the ten most recent years based on the assumption that physical activities at work more than ten years ago have little impact, if any. Third, we calculated IRR within selected DISCO-88 major groups with large ranges of physical activities as an alternative way to account for potential confounding by social factors. Fourth, we repeated the analyses of short-term effects using models with adjustment for cumulative exposure accrued before the previous calendar year. Finally, we adjusted analyses of long-term standing/walking for effects of lifting.
Supplementary analyses. To examine potential interactions between lifting and the strong risk factors for AMI, smoking and BMI, we performed sex-stratified crude and fully adjusted analyses using models that in addition to main effects as continuous variables also included the product of cumulative lifting and (i) cumulative smoking and (ii) years with BMI in the upper tertile. All analyses were carried out in SAS 9.4 (SAS Institute, Cary, NC, USA) on a platform at Statistics Denmark.

Results

The study population included 1.15 million individuals with 41.5 million person-years equally divided in years before and after start of follow-up. The number of prehospital deaths due to AMI during follow-up and incident hospitalizations for AMI was 22 037 among men and 6942 among women. A skewed distribution according to lifting was evident for highest education and social position, and for smoking, BMI and LTPA (table 1). All covariates - except LTPA - exhibited robust prospective and mutually independent associations with AMI in the expected direction (supplementary table S1). LTPA was, as expected, associated with reduced risk of AMI in analyses only adjusting for age, but not in fully adjusted analyses (table S1).

Lifting at work

Among men, the short-term risk of AMI was not associated with lifting (table 2). The fully adjusted long-term risk increased with increasing cumulative lifting (tonyears) up to the previous year reaching a maximum IRR of 1.09 (table 2). The associations were attenuated or disappeared in models using cumulative exposure before start of follow-up, in models based on the most recent ten years (supplementary table S2), and in three of four social strata with large ranges of cumulative lifting up to the previous year (see supplementary tables S3 for exposure ranges and S4 for results).
Among women, the fully adjusted short-term risk of AMI tended to increase with increasing lifting exposure reaching a maximum IRR of 1.16 (table 2), even when adjusted for cumulative lifting accrued before the previous calendar year (results not shown). The fully adjusted long-term risk increased with increasing cumulative lifting (ton-years) up to the previous year. Associations were also seen in sensitivity analyses only including cumulative exposure before start of follow-up (table S2), but not in models based on the previous ten years (table S2). Moreover, indications of higher risk with higher levels of exposure (intensity times duration) were seen in two of four social strata with large ranges of cumulative lifting up to the previous year (see table S3 for exposure ranges and table S4 for results), but tests for trend were not significant at the 5% level in any of these analyses (table S4).
There were no indications of an increased risk of AMI due to interaction between cumulative lifting and cumulative smoking in either sex in fully adjusted models (OR 1.00, 95% CI 0.99-1.01 in men; OR 1.01, 95% CI 0.99-1.02 in women). Corresponding figures for interaction between cumulative lifting and cumulative BMI were OR 0.99, 95% CI 0.99-1.00, for men and OR 0.98, 95% CI 0.97-1.00, for women.

Standing/walking at work

Among men, the fully adjusted models did not consistently indicate associations between standing/walking at work and short- or long-term risk of AMI (table 3 and table S2).

Among women, there were no indications of increased short-term risks (table 3). The fully adjusted long-term risk increased with increasing cumulative standing/walking up to the previous year (reaching a maximum IRR of 1.18), but the association was attenuated when adjusting for longterm lifting (maximum IRR 1.11, 95% CI 1.001.23) and the trend became insignificant (P=0.08). Moreover, this relationship was neither found in models only including cumulative exposure before start of follow-up nor in models based on the previous ten years (table S2).

Discussion

In this register-based nationwide follow-up study using JEM for assessment of physical activities, we found indications of slightly elevated long-term risks of AMI associated with lifting at work, while no consistent associations were observed for standing/walking.

Strengths of the study are the large study population covering the entire spectrum of occupations, a follow-up period of 20 years, almost complete data, assessment of occupational and cardiovascular risk factors from young age, assignment of independent information on specific physical activities at work, reliable outcome ascertainment, comprehensive adjustment for social factors, adjustment for smoking, BMI and LTPA and statistical power to perform sex-specific analyses and analyses stratified by social position.

Limitations are primarily related to exposure misclassification, lack of detailed information on LTPA, residual confounding and the potential for a healthy worker survivor effect. Exposure assignment based on JEM inherently causes misclassification - let alone because a JEM does not reflect variation in exposure among individuals in the same occupations. As the within-occupation variation relative to the between- occupation variation increases, still larger study populations will be needed to separate true effects from statistical noise (41). The implication of exposure misclassification is inability to detect effects of the entire range of individual exposures, but risk estimates of the occurring average exposure across occupations are not expected to be attenuated. Since the ranges of job specific average exposures to lifting and standing/walking were rather wide, the study provides valuable information. However, risks related to the very high end of exposures - for instance lifting >10 tons/day - cannot be evaluated in this study since the highest JEM-based average lifting for an occupation was 3.5 tons/day. Further evidence regarding the validity of the JEM is the rather strong crude exposure-outcome associations in the expected direction observed in this study and the ability to predict several other outcomes in earlier studies (34-37).

The standing/walking JEM does not distinguish between standing and walking. We cannot exclude the possibility that prolonged standing is associated with an increased risk and walking without prolonged standing with a decreased risk resulting in no-risk when combined as in our study. However, to the best of our knowledge, there are no data to indicate that standing at work is a risk factor for AMI. Of note, a recent study included standing (shop assistants, security guards) in physical activities in parallel with lifting and leisure time physical activities and reported no increase in cardiovascular mortality (42). The design does not allow for examination of immediate (triggering) effects since the most detailed exposure resolution is one calendar year. For instance, it might be hypothesized that an acute severe exertion of heavy lifting at work might trigger AMI. This might be explored in future case-crossover studies. On the other hand, earlier epidemiological evidence is based upon the hypothesis that (unspecified) physical activities at work result in gradual cumulative damage to the cardiovascular system (16).

Residual confounding. The study benefits from sufficient statistical power to enable comprehensive adjustment for a range of well-established risk factors which all except LTPA independently predicted the risk of AMI. In many analyses, risks related to physical activities were strongly attenuated towards null in fully adjusted models. Socio-economic position is a strong risk factor of AMI and was accounted for by highest education, employment status and social position (DISCO-88 first digit groups) - and by analyses restricted to selected social strata with wide ranges of exposure. We did not have data on individual cardiovascular risk factors except that we were able to exclude persons who had been hospitalized due to IHD before start of follow-up. However, the use of lifestyle JEM for smoking and BMI performed well. Both factors were robustly and independently associated with AMI risk in both men and women, even after adjustment for highest education, social position and employment status. This adds to the evidence that these sex-, age-, and period-specific lifestyle JEM are valuable tools to adjust for risks related to lifestyle in register-studies without access to individual information (24).

However, the LTPA JEM did not consistently predict a reduced risk of AMI. This is perhaps not surprising since LTPA is prevalent regardless of type of occupation and low and high levels of LTPA occur in all job groups. . Nevertheless, this JEM serves the purpose of controlling confounding since exposure is also defined by JEM.

Other potentially confounding factors, such as heredity, hypertension, hyperlipidemia, diabetes, major depression (27), job strain (22), environmental (43) and occupational noise (44), shift work (45) and airborne particulate exposure (46), were not explicitly controlled for. Therefore, we are not able to exclude the possibility of residual confounding.

Healthy worker survivor effect. Individuals with emerging cardiovascular disease may leave physically demanding jobs long before death or hospitalisation for AMI leading to a healthy worker survivor effect (bias towards the null). This was probably counteracted by analyses only based upon exposure before start of follow-up, where cohort members were 30-50 years old and by including employment status as a covariate during follow-up.

Earlier findings

Although an increasing number of studies have addressed cardiovascular morbidity in relation to physical activities at work, direct comparisons of results are impeded by vaguely defined exposures. With few exceptions (21, 47), earlier studies relied on individual self-report of physical activities at one point in time and often combined various activities into one measure (9, 12-14, 19, 48). For example, one study defined physical activity as "standing and walking most of the time with quite a bit of carrying or lifting heavy burdens or work that requires vigorous or strenuous physical activity" (12) and another study defined physical activity as "most of the time you walk, and you often have to walk upstairs and lift various items (eg, mail delivery and construction work). Or you have heavy physical work. You carry heavy burdens and carry out physically strenuous work (eg, digging and shoveling)" (9). A Finnish study used a more transparent approach by converting self-report data on time spent in various activities into energy requirements (kcal/kg/hour) of these activities (sitting, standing, walking, climbing stairs - but without a category for heavier work) (13). Thus, the inability to distinguish more physically demanding work is a limitation of most previous studies. Moreover, confounding by individual and social risk factors is likely in many studies (17).

Sex differences. While most earlier studies reported effects in men (9, 12, 13, 19, 48), this study found most consistent associations in women. Biologically, it does not seem plausible that women are more susceptible to physical activities at work than men. The existence of sex-specific differences in the pathophysiology and pathogenesis of AMI is widely acknowledged (49) and some risk factors are more potent in women. However, men and women share all established risk/protective factors such as smoking, high BMI, exercise, diabetes, hypertension, and depression (27). It is therefore hard to figure out why physical activities at work would be deleterious in one sex but not in the other. In this study, we performed sex-stratified analysis to demonstrate consistency. It also seems unlikely that occupational exposure patterns and levels would confer a higher risk among women. However, the level of physical activity relative to the individual maximal capacity rather than the absolute level may be of importance (13). If women with physically demanding work have a higher work load relative to their maximal physical capacity than men, this might in fact explain sex differences, but this potential explanation of our findings seems less likely given the fact that we used lower category boundaries for lifting for women than for men. Of note, a large study of nurses with long follow-up found increased rate of incident IHD with increasing level of self-reported physical activities at work across all strata of selfreported LTPA (14). In this study physical activities were categorized as mainly sedentary (low), standing/ walking (medium) and lifting/carrying/ heavy/fast/ physically exerting work (high) (14).

Leisure time physical activity versus physical activities at work. It has been argued that the intensity of physical activity at work is too low to improve cardiorespiratory fitness and cardiovascular health (16). But this seems not to fit with evidence that even moderate physical activity such as brisk walking for 2.5 hours/week is related to substantially decreased cardiovascular mortality and that vigorous frequent physical training only accomplishes moderate additional risk reduction (4, 5). However, physical activity at work is distinguished by other characteristics.

It has been argued that physical activity at work is associated with an elevation of the 24-hour heart rate and blood pressure (which is related to increased cardiovascular disease risk), insufficient recovery and work control and increased level of low-grade inflammation (16). Studies based on objective recordings of LTPA and specific physical activities at work are needed to corroborate or refute the relevance of these factors.

Concluding remarks

This study provides limited support to the hypothesis that long-term lifting and standing/walking at work are related to an increased risk of AMI.

Acknowledgement

The Danish Working Environment Research Fund supported this study (43-2014-03 / 20140016763). Sigurd Mikkelsen is acknowledged for his contribution to the development of the initial study protocol.

Sidebar

We know that leisure-time physical activity is related to reduced cardiovascular morbidity, but some recent papers provide evidence that physical activities at work are related to increased risk. We used job exposure matrices for assessment of physical activities at work, we found indications of slightly elevated long-term risks of acute myocardial infarction associated with lifting, but not with standing/walking.

Refers to the following texts of the Journal: 2005;31(2):97-107 2007;33(6):425-434 2010;36(5):357-365 2015;41(2):124-139 2016;42(6):481-489

The following articles refer to this text: [online first; 20 January 2020]; 2020;46(3):231T234

Key terms: acute myocardial infarction; cohort study; epidemiology; heart disease; heavy lifting; JEM; job-exposure matrix; occupation; physical activity; standing; strenuous work; walking

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31725896

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Bonde JPE, Flachs EM, Madsen IEH, Petersen SB, Andersen JH, Hansen J, Jørgensen EB, Kolstad H, Holtermann A, Schlünssen V, Svendsen SW. Acute myocardial infarction in relation to physical activities at work: a nationwide follow-up study based on job-exposure matrices. Scand J Work Environ Health. 2020;46(3):268-277. doi:10.5271/sjweh.3863

Keyterms cohort study; epidemiology; heart disease; heavy lifting; JEM; occupation; standing; strenuous work; walking.

Correspondence to: Jens Peter Bonde, Bispebjerg Frederiksberg Hospitals, Department of Occupational and Environmental Medicine, Bispebjerg Bakke 23, DK-Copenhagen 2400 NV, Denmark. [E-mail: Jens.Peter.Ellekilde.Bonde@regionh.dk]

Footnote

1 of Occupational and Environmental Medicine, Bispebjerg-Frederiksberg Hospital, Copenhagen, Denmark.

2 National Research Center for the Working Environment, Copenhagen, Denmark.

3 Danish Ramazzini Center, Department of Occupational Medicine, Regional Hospital West Jutland - University Research Clinic, Herning, Denmark.

4 Danish Cancer Society Research Center, Copenhagen, Denmark.

5 Department of Biostatistics, University of Copenhagen, Denmark.

6 Department of Occupational Medicine, Danish Ramazzini Center, Aarhus University Hospital, Aarhus, Denmark.

7 Department of Public Health, Danish Ramazzini Center, University of Aarhus, Aarhus, Denmark.

References

References

1. Sofi F, Capalbo A, Cesari F, Abbate R, Gensini GF. Physical activity during leisure time and primary prevention of coronary heart disease: an updated meta-analysis of cohort studies. Eur J Cardiovasc Prev Rehabil 2008 Jun;15(3):24757. https://doi.org/10.1097/HJR.0b013e3282f232ac.

2. Nocon M, Hiemann T, Müller-Riemenschneider F, Thalau F, Roll S, Willich SN. Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. Eur J Cardiovasc Prev Rehabil 2008 Jun;15(3):239-46. https://doi.org/10.1097/ HJR.0b013e3282f55e09.
3. Saint-Maurice PF, Coughlan D, Kelly SP, Keadle SK, Cook MB, Carlson SA et al. Association of leisuretime physical activity across the adult life course with all-cause and cause-specific mortality. JAMA Netw Open 2019 Mar;2(3):e190355. https://doi.org/10.1001/ jamanetworkopen.2019.0355.
4. Zhao M, Veeranki SP, Li S, Steffen LM, Xi B. Beneficial associations of low and large doses of leisure time physical activity with all-cause, cardiovascular disease and cancer mortality: a national cohort study of 88,140 US adults. Br J Sports Med 2019 Nov;53(22):1405-11. https://doi. org/10.1136/bjsports-2018-099254.
5. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA et al. The physical activity guidelines for Americans. JAMA 2018 Nov;320(19):2020-8. https://doi. org/10.1001/jama.2018.14854.
6. Paffenbarger RS Jr, Laughlin ME, Gima AS, Black RA. Work activity of longshoremen as related to death from coronary heart disease and stroke. N Engl J Med 1970 May;282(20): 1109-14. https://doi.org/10.1056/ NEJM197005142822001.
7. Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. Lancet 1953 Nov;262(6795):1053-7. https://doi. org/10.1016/S0140-6736(53)90665-5.
8. Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. Lancet 1953 Nov;262(6796):ini-20. https://doi. org/10.1016/S0140-6736(53)91495-0.
9. Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. Scand J Work Environ Health 2010 Sep;36(5):357-65. https://doi. org/10.5271/sjweh.2913.
10. Holtermann A, Mortensen OS, Søgaard K, Gyntelberg F, Suadicani P. Risk factors for ischaemic heart disease mortality among men with different occupational physical demands. A 30-year prospective cohort study. BMJ Open 2012 Jan;2(1):e000279. https://doi.org/10.1136/ bmjopen-2011-000279.
11. Holtermann A, Burr H, Hansen JV, Krause N, Søgaard K, Mortensen OS. Occupational physical activity and mortality among Danish workers. Int Arch Occup Environ Health 2012 Apr;85(3):305-10. https://doi.org/10.1007/s00420011-0668-x.
12. Petersen CB, Eriksen L, Tolstrup JS, Søgaard K, Grønbaek M, Holtermann A. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. BMC Public Health 2012 Dec;12:1070. https://doi.org/10.1186/14712458-12-1070.
13. Krause N, Brand RJ, Arah OA, Kauhanen J. Occupational physical activity and 20-year incidence of acute myocardial infarction: results from the Kuopio Ischemic Heart Disease Risk Factor Study. Scand J Work Environ Health 2015 Mar;41(2):124-39. https://doi.org/10.5271/sjweh.3476.
14. Allesøe K, Holtermann A, Aadahl M, Thomsen JF, Hundrup YA, Søgaard K. High occupational physical activity and risk of ischaemic heart disease in women: the interplay with physical activity during leisure time. Eur J Prev Cardiol 2015 Dec;22(12):1601-8. https://doi. org/10.1177/2047487314554866.
15. Coenen P, Huysmans MA, Holtermann A, Krause N, van Mechelen W, Straker LM et al. Do highly physically active workers die early? A systematic review with metaanalysis of data from 193 696 participants. Br J Sports Med 2018 Oct;52(20):1320-6. https://doi.org/10.1136/ bjsports-2017-098540.
16. Holtermann A, Krause N, van der Beek AJ, Straker L. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med 2018 Feb;52(3):149-50. https://doi.org/10.1136/ bjsports-2017-097965.
17. Shephard RJ. Is there a 'recent occupational paradox' where highly active physically active workers die early? Or are there failures in some study methods? Br J Sports Med 2019 Mar;E-pub ahead of print]:bjsports-2018-100344. https:// doi.org/10.1136/bjsports-2018-100344.
18. Richard A, Martin B, Wanner M, Eichholzer M, Rohrmann S. Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. J Phys Act Health

2015 Feb;12(2):184-92. https://doi.org/10.1123/jpah.2013-0198.
19. Clays E, Casini A, Van Herck K, De Bacquer D, Kittel F, De Backer G et al. Do psychosocial job resources buffer the relation between physical work demands and coronary heart disease? A prospective study among men. Int Arch Occup Environ Health 2016 Nov;89(8):1299-307. https:// doi.org/10.1007/s00420-016-1165-z.
20. Hayashi R, Iso H, Cui R, Tamakoshi A, Group JS; JACC Study Group. Occupational physical activity in relation to risk of cardiovascular mortality: The Japan Collaborative Cohort Study for Evaluation for Cancer Risk (JACC Study). Prev Med 2016 Aug;89:286-91. https://doi.org/10.1016/j. ypmed.2016.06.008.
21. Hannerz H, Holtermann A. Ischaemic heart disease among workers in occupations associated with heavy lifting. Int J Occup Med Environ Health 2016;29(1):129-36. https://doi. org/10.13075/ijomeh.1896.00472.
22. Kivimäki M, Nyberg ST, Batty GD, Fransson EI, Heikkilä K, Alfredsson L et al.; IPD-Work Consortium. Job strain as a risk factor for coronary heart disease: a collaborative meta-analysis of individual participant data. Lancet 2012 Oct;380(9852):1491-7. https://doi.org/10.1016/S01406736(12)60994-5.
23. Evanoff B, Yung M, Buckner-Petty S, Baca M, Andersen JH, Roquelaure Y et al. Cross-national comparison of two general population job exposure matrices for physical work exposures. Occup Environ Med 2019 Aug;76(8):567-72. https://doi.org/10.1136/oemed-2018-105408.
24. Bondo Petersen S, Flachs EM, Prescott EI, Tjønneland A, Osler M, Andersen I et al. Job-exposure matrices addressing lifestyle to be applied in register-based occupational health studies. Occup Environ Med 2018 Dec;75(12):890-7. https://doi.org/10.1136/oemed-2018-104991.
25. Pukkala E, Guo J, Kyyrönen P, Lindbohm ML, Sallmén M, Kauppinen T. National job-exposure matrix in analyses of census-based estimates of occupational cancer risk. Scand J Work Environ Health 2005 Apr;31(2):97-107. https://doi. org/10.5271/sjweh.856.
26. Armstrong BG. Effect of measurement error on epidemiological studies of environmental and occupational exposures. Occup Environ Med 1998 Oct;55(10):651-6. https://doi.org/10.1136/oem.55.10.651.
27. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F et al.; INTERHEART Study Investigators. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet 2004 Sep;364(9438):93752. https://doi.org/10.1016/S0140-6736(04)17018-9.
28. Denmark. S. Disco-88: Statistics denmark's standard classification of occupations. Copenhagen: Danmarks Statistik, 1996.
29. Flachs EM, Petersen SE, Kolstad HK, Schlünssen V, Svendsen SW, Hansen J et al. Cohort profile: DOC·X: a nationwide Danish occupational cohort with eXposure data - an open research resource. Int J Epidemiol 2019;dyz110.
30. The Employment Classification Module AKM. Avalaible from: http://econ.au.dk/the-national-centre-for-registerbased-research/danish-registers/the-employmentclassification-module-akm/. Aarhus University. [Accessed 1.5.2019].
31. Petersson F, Baadsgaard M, Thygesen LC. Danish registers on personal labour market affiliation. Scand J Public Health 2011 Jul;39(7 Suppl):95-8. https://doi. org/10.1177/1403494811408483.
32. Rubak TS, Svendsen SW, Andersen JH, Haahr JP, Kryger A, Jensen LD et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014 Jun;15:204. https://doi.org/10.1186/14712474-15-204.
33. Rubak TS, Svendsen SW, Andersen JH, Haahr JP, Kryger A, Jensen LD et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014 Jun;15:204. https://doi.org/10.1186/14712474-15-204.
34. Sommer TG, Svendsen SW, Frost P. Sickness absence and permanent work disability in relation to upper- and lower-body pain and occupational mechanical and psychosocial exposures. Scand J Work Environ Health 2016 Jun;42(6):481-9. https://doi.org/10.5271/sjweh.3600.
35. Tabatabaeifar S, Frost P, Andersen JH, Jensen LD, Thomsen JF, Svendsen SW. Varicose veins in the lower extremities in relation to occupational mechanical exposures: a longitudinal study. Occup Environ Med 2015

May;72(5):330-7. https:// doi.org/10.1136/oemed-2014-102495.
36. Vad MV, Frost P, Rosenberg J, Andersen JH, Svendsen SW. Inguinal hernia repair among men in relation to occupational mechanical exposures and lifestyle factors: a longitudinal study. Occup Environ Med 2017 Nov;74(11):769-75. https://doi.org/10.1136/oemed-2016-104160.
37. Rubak TS, Svendsen SW, Søballe K, Frost P. Total hip replacement due to primary osteoarthritis in relation to cumulative occupational exposures and lifestyle factors: a nationwide nested case-control study. Arthritis Care Res (Hoboken) 2014 Oct;66(10):1496-505. https://doi. org/10.1002/acr.22326.
38. Vad MV, Frost P, Bay-Nielsen M, Svendsen SW. Impact of occupational mechanical exposures on risk of lateral and medial inguinal hernia requiring surgical repair. Occup Environ Med 2012 Nov;69(11):802-9. https://doi. org/10.1136/oemed-2012-100787.
39. Madsen IE, Gupta N, Budtz-Jørgensen E, Bonde JP, Framke E, Flachs EM et al. Physical work demands and psychosocial working conditions as predictors of musculoskeletal pain: a cohort study comparing self-reported and job exposure matrix measurements. Occup Environ Med 2018 Oct;75(10):752-8. https://doi. org/10.1136/oemed-2018-105151.
40. Helweg-Larsen K. The Danish Register of Causes of Death. Scand J Public Health 2011 Jul;39(7 Suppl):26-9. https:// doi.org/10.1177/1403494811399958.
41. Kromhout H, Heederik D. Occupational epidemiology in the rubber industry: implications of exposure variability. Am J Ind Med 1995 Feb;27(2):171-85. https://doi.org/10.1002/ ajim.4700270203.
42. Mok A, Khaw KT, Luben R, Wareham N, Brage S. Physical activity trajectories and mortality: population based cohort study. BMJ 2019 Jun;365:l2323. https://doi.org/10.1136/ bmj.l2323.
43. Stansfeld S, Crombie R. Cardiovascular effects of environmental noise: research in the United Kingdom. Noise Health 2011 May-Jun;13(52):229-33. https://doi. org/10.4103/1463-1741.80159.
44. Tomei G, Fioravanti M, Cerratti D, Sancini A, Tomao E, Rosati MV et al. Occupational exposure to noise and the cardiovascular system: a meta-analysis. Sci Total Environ 2010 Jan;408(4):681-9. https://doi.org/10.1016/j. scitotenv.2009.10.071.
45. Virkkunen H, Härmä M, Kauppinen T, Tenkanen L. Shift work, occupational noise and physical workload with ensuing development of blood pressure and their joint effect on the risk of coronary heart disease. Scand J Work Environ Health 2007 Dec;33(6):425-34. https://doi.org/10.5271/ sjweh.1170.
46. Mocevic E, Kristiansen P, Bonde JP. Risk of ischemic heart disease following occupational exposure to welding fumes: a systematic review with meta-analysis. Int Arch Occup Environ Health 2015 Apr;88(3):259-72. https://doi. org/10.1007/s00420-014-0965-2.
47. Paffenbarger RS, Hale WE. Work activity and coronary heart mortality. N Engl J Med 1975 Mar;292(11):545-50. https:// doi.org/10.1056/NEJM197503132921101.
48. Kristal-Boneh E, Harari G, Melamed S, Froom P. Association of physical activity at work with mortality in Israeli industrial employees: the CORDIS study. J Occup Environ Med 2000 Feb;42(2):127-35. https://doi. org/10.1097/00043764-200002000-00005.
49. Mehta LS, Beckie TM, DeVon HA, Grines CL, Krumholz HM, Johnson MN et al.; American Heart Association Cardiovascular Disease in Women and Special Populations Committee of the Council on Clinical Cardiology, Council on Epidemiology and Prevention, Council on Cardiovascular and Stroke Nursing, and Council on Quality of Care and Outcomes Research. Acute myocardial infarction in women: a scientific statement from the American Heart Association. Circulation 2016 Mar;133(9):916-47. https:// doi.org/10.1161/CIR.0000000000000351.
50. Sundbøll J, Adelborg K, Munch T, Frøslev T, Sørensen HT, Bøtker HE et al. Positive predictive value of cardiovascular diagnoses in the Danish National Patient Registry: a validation study. BMJ Open 2016 Nov;6(11):e012832. https://doi.org/10.1136/bmjopen-2016-012832. Received for publication: 27 August 2019

DETAILS

Subject:	Population; Estimates; Dose-response effects; Women; Hoisting; Codes; Myocardial infarction; Exposure; Statistical analysis; Risk; Men; Age; Hypotheses; Heart attacks; Confidence intervals; Classification; Sensitivity analysis; Regression analysis; Population studies; Lifestyles; Employment; Wages &salaries
Business indexing term:	Subject: Employment Wages &salaries
Location:	Denmark
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	268-277,268A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3863
ProQuest document ID:	2406985136
Document URL:	https://www.proquest.com/scholarly-journals/acute-myocardial-infarction-relation-physical/docview/2406985136/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2022-05-06

Shift work and physical inactivity: findings from the Finnish Public Sector Study with objective working hour data

Cheng, Wan-Ju, PhD [1] ; Härmä, Mikko, PhD [2] ; Ropponen, Annina, PhD [2] ; Karhula, Kati, PhD [2] ; Koskinen, Aki, MSc [2] ; Oksanen, Tuula, PhD [1] Department of Psychiatry, China Medical University Hospital, Taichung, Taiwan. [2] Finnish Institute of Occupational Health, Helsinki, Finland.

ABSTRACT (ENGLISH)

Objectives Shift work is a risk factor for chronic diseases, and physical inactivity can have an influence on this association. We examined whether intra-individual changes in working time characteristics were associated with changes in physical inactivity and examined the risk factors for physical inactivity among shift workers in a 17-year longitudinal study cohort. Methods Study participants were 95 177 employees from the Finnish public sector. Work schedule information was based on questionnaire responses and additional register-based working time characteristics for 26 042 employees. The associations between working time characteristics and physical inactivity were examined using a fixed-effects logistic model. To investigate the risk factors for physical inactivity among shift workers, the odds ratios (OR) of worktime control and having small children were calculated. Results Compared with day work, shift work without night shifts was associated with physical inactivity among men [OR 1.38, 95% confidence interval (CI) 1.09-1.74], whereas shift work with night shifts was negatively associated with physical inactivity among women (OR 0.85, 95% CI 0.76-0.96). Register-based working time data confirmed that workers with a higher percentage of night shifts had a lower risk of physical inactivity. Having small children was associated with physical inactivity among shift workers (OR 1.47, 95% CI 1.32-1.65). Conclusions Both survey and objective working hour data revealed that workers having work schedules with night shifts were more likely to be physically active. Having small children was a risk factor for physical inactivity among shift workers.

FULL TEXT

Headnote

Cheng W-J, Härmä M, Ropponen A, Karhula K, Koskinen A, Oksanen T. Shift work and physical inactivity: findings from the Finnish Public Sector Study with objective working hour data. Scand J Work Environ Health. 2020;46(3):293-301. doi:10.5271/sjweh.3868

Objectives Shift work is a risk factor for chronic diseases, and physical inactivity can have an influence on this association. We examined whether intra-individual changes in working time characteristics were associated with changes in physical inactivity and examined the risk factors for physical inactivity among shift workers in a 17-year longitudinal study cohort.

Methods Study participants were 95 177 employees from the Finnish public sector. Work schedule information was based on questionnaire responses and additional register-based working time characteristics for 26 042 employees. The associations between working time characteristics and physical inactivity were examined using a fixed-effects logistic model. To investigate the risk factors for physical inactivity among shift workers, the odds ratios (OR) of

worktime control and having small children were calculated.
Results Compared with day work, shift work without night shifts was associated with physical inactivity among men [OR 1.38, 95% confidence interval (CI) 1.09-1.74], whereas shift work with night shifts was negatively associated with physical inactivity among women (OR 0.85, 95% CI 0.76-0.96). Register-based working time data confirmed that workers with a higher percentage of night shifts had a lower risk of physical inactivity. Having small children was associated with physical inactivity among shift workers (OR 1.47, 95% CI 1.32-1.65).
Conclusions Both survey and objective working hour data revealed that workers having work schedules with night shifts were more likely to be physically active. Having small children was a risk factor for physical inactivity among shift workers.
Key terms Finland; fixed effect; fixed-effects modeling; leisure-time physical activity; longitudinal study; physical activity; shift worker; work schedule; working time.
Shift work is associated with sleep disturbances, stroke, breast cancer, and several chronic diseases such as cardiovascular diseases and metabolic diseases (1). Lack of physical activity has been shown to be a direct risk factor for cardiovascular and metabolic diseases (2); therefore, physical activity is recommended for shift workers. Because shift work is often necessary in the modern workplace, strategies aiming to attenuate its adverse health effects have been tested (3). Systematic reviews have determined that physical activity-based interventions improved the body composition and sleep of shift workers (4, 5). It has also been suggested that shift workers engage in less physical activity compared with day workers because they have difficulty participating in group-based physical activities or activities in the early evening (6). However, evidence regarding the association between shift work and physical inactivity is inconsistent.
Several cross-sectional studies have reported an association between shift work and less engagement in leisure-time physical activity (7-9), whereas others have found either no (10-13) or a negative (14-16) association. Longitudinal studies are scarce; no association between 1-year changes in work schedule and changes in physical activity was discerned in one (17). Another longitudinal study determined that a long history of night work was associated with more vigorous physical activity among female workers (18). The same study also determined that "never" and "ever" night workers differed significantly in socioeconomic status and health behaviors. Therefore, in cross-sectional studies, the difference observed in the physical activity between day and night workers was likely to have been confounded by participants' personal characteristics. Lately, several studies utilizing objective measurement of physical activity documented no association between shift work and total leisure-time physical activity (19-22).
Variations in measurement methods and definitions of work schedule have led to contrasting results between studies as well. Workers with rotating or fixed shifts, as well as those with shift work with or without night shifts, are usually categorized in the "shift work group" even though they may exhibit different levels of physical activity. For example, physical activity was found to be positively associated with irregularly rotating shifts, but negatively associated with fixed night work (21). Objective quantification of working time characteristics has rarely been used, with the exception of one study of police officers that revealed increased vigorous physical activity in shift workers (16). Apart from shift work, highly physical manual work may prevent individuals from desiring to engage in physical activity after work (9, 10) and workers of lower socioeconomic status may not have the physical resources to engage in strenuous physical activity after working hours (23). Furthermore, participants in previous studies were recruited from different genders and occupational groups in which the associations between shift work and physical activity differ. In Finnish cohorts, women have generally exhibited less physical activity (23-25), but gender interaction in the association between shift work and physical activity has not been examined.
To increase physical activity among shift workers, barriers related to work and family conditions should be taken into account. Working time control refers to autonomy with regard to work time (26) and has been found to be lower among shift workers compared to dayworkers (27-29). Furthermore, having small children was associated with physical inactivity in one study (11) but not in another study that adjusted for marital status (10). Nevertheless, none of these risk factors for physical inactivity have been examined in longitudinal studies.

In summary, previous studies on the associations between shift work and physical activity have tended to lack detailed information concerning characteristics of working hours and have been based on limited sample sizes and a cross-sectional design, which is vulnerable to selection bias and reverse causal relationships. To address these limitations, we used a large longitudinal cohort from the Finnish Public Sector (FPS) Study to examine the associations between intra-individual changes in shift schedule and changes in physical activity. We further linked the survey data with objective registry data of daily working hours to examine the associations between the more specific working hour characteristics and physical inactivity. To identify risk factors for physical inactivity among shift workers, we examined the associations between changes in physical activity and changes in family and work conditions with fixed-effects models.

Methods

Study participants

Data from two cohorts of the FPS Study were used. In the first cohort, information on exposure to shift work was based on 2000-2017 survey information (referred as the "survey cohort"). In the other cohort, information regarding exposure to shift work was based on 20072017 registry data (referred as the "register cohort"; figure 1). The FPS Study comprises two parts (i): the 10-Town Study, a study of local government employees in 11 towns, and (ii) the Work and Health in Finnish Hospital Personnel Study, a study conducted within 21 hospitals. We used six waves of survey information from the FPS Study: 2000, 2004, 2008, 2012, 2014, and 2016 from the 10-Town Study and 2000, 2004, 2008, 2012, 2015, and 2017 from the Work and Health in Finnish Hospital Personnel Study. Therefore, we obtained information regarding physical activity for six consecutive time points, and this information was linked to information on exposure to shift work attained from the same survey (the survey cohort) or to registry data of working hour characteristics of the preceding year (for the last four time points only; the register cohort). The response rates of the six waves of the survey were 67-72%. The Ethics Committee of the Hospital District of Helsinki and Uusimaa (HUS) approved the FPS Study (HUS 1210/2016).

A total of 149 303 participants participated in at least one of the survey waves. To examine changes in physical activity over time, only those who had participated in at least two surveys (N=96 651) were included in the survey cohort. The largest occupational groups in the survey cohort were practical nurses (20%), registered nurses (15%), primary school and preschool teachers (8%), and secondary school teachers (6%).

The registry data of working hours of the register cohort were obtained from Titania® shift-scheduling software, which was used by the hospital workers of the FPS Study cohort (including the whole shift-working population and the majority of the day-working population of all the studied hospitals) during the period of 2007-2017. We included only workers who had at least 150 shifts and 300 contract days during the preceding 365 days and those having participated in at least two surveys. Finally, 869 physicians were excluded because their on-call data were not available, whereas nonphysician workers did not have on-call work, and all their working hours were recorded in the registry data. Another 214 employees were excluded due to missing physical activity data, leaving a total of 26 042 participants in the register cohort (figure 1). The main occupational groups in the register cohort were registered nurses (35%) and practical nurses (33%).

Assessment of shift work and working time

Participants in the survey cohort were classified as day workers, shift workers without night shifts, shift workers with night shifts, and fixed night workers on the basis of the survey data. In the 10-Town Study, participants in the 2000 and 2004 waves were asked "Is your work regular day work?". If the answer was negative, they were then asked to indicate if their work included evening, night, or weekend shifts. Participants were classified as (i) day workers if they answered "yes" to the initial question, (ii) shift workers without night shifts if they answered "no" to the initial question and then indicated that their work included evening shifts but not night shifts, or (iii) shift workers with night shifts if they indicated having both evening and night shifts. Participants selecting any other combination of responses were excluded from the analyses. In the 2008 and later waves of the 10-Town Study and all waves of the Work and Health in Finnish Hospital Personnel Study, participants were classified according to whether they described their current work as either day work, shift work without night shifts, shift work with night shifts, fixed night work, or other irregular work. Participants who had another irregular work schedule were excluded. Finally, participants with invalid or missing values on shift schedule (N=1111) and physical activity (N=363) were excluded from the survey cohort, leaving a total of 95 177 participants in the survey cohort (figure 1). The questionnaire items used have been validated against the registry data of working hours (registry data) (30).

The registry data of daily working hours of the register cohort for 365 days prior to each survey were used. On the basis of the daily start and end times of the shifts, several working hour characteristics were calculated on the basis of the main dimensions of the working hours (length, timing, recovery, and social aspects), as in previous studies (30-32). The variables used in this study were average weekly working hours, the percentage of evening shifts and night shifts, percentage of quick returns (<11-hour shift interval) of all shift intervals, percentage of single free days of all the free days, percentage of >48-hour weeks, and percentage of long shifts (>12 hours) (31). We selected these working hour characteristics on the basis of the hypothesis that length of working hours, timing of work shifts, and time for recovery could influence the possibility of or access to leisure time physical activity. According to the distribution of working hour variables (supplementary table S1, www.sjweh.fi/show_abstract.php?abstract_id=3868) and the literature (33), the working hour variables were dichotomized using a cutoff of >10% for >48-hour weeks, long shifts, and night shifts, and >25% for the other variables.

Assessment of physical inactivity

In all six survey data waves, participants were asked how many hours of physical activity they had per week on average during leisure time or commuting within the past year. The options were: 0,<30 minutes, 0.5-1, 2-3, and >4 hours. They indicated hours for each of the four physical activities or activities with similar intensity: walking, brisk walking, jogging, and running. The participants were categorized as being physically inactive if they reported brisk walking, jogging, or running for<30 minutes per week (34-36), otherwise, they were categorized as being physically active. Those who reported only walking were categorized as physically inactive as well (34-36). We also analyzed whether the participants were lacking in vigorous physical activity, defined as having<30 minutes of jogging, running, or physical activities with similar intensity each week.

Other variables

Age, gender, occupation, having small children (<6 years old), worktime control, and weekly working hours were self-reported in the survey questionnaire. The worktime control was measured using seven questions (i): control over length of day, (ii) control over the beginning and end of a workday, (iii) opportunities to take breaks, (iv) opportunities to deal with private matters during the workday, (v) control over scheduling of shifts, (vi) control over scheduling of paid days off and vacations, and (vii) opportunities to take unpaid leave (37). Responses to each item were given on a 5-point scale ranging from very little (score 1) to very much (score 5). The mean of overall worktime control, control over daily hours (items i and ii), and control over time off (items iii-vii) were divided into tertiles as high, intermediate, and low worktime control (28).

Participants were categorized as blue- or white-collar workers according to self-reported occupations, using the first digit of their occupational code in the Finnish National Classification of Occupations 2001 (38). Legislators, managers, professionals, technicians, clerks, and service and sales workers were categorized as whitecollar workers. Agricultural and fishery workers, craft workers, machine operators and assemblers, and elementary occupations were categorized as blue-collar workers.

Due to changes in the questionnaire over the six survey waves, data regarding having small children were absent in the 2014 survey, and 24%-45% of responses were missing in the other surveys. Self-reported working hours were available only in the 2000-2015 Work and Health in Finnish Hospital Personnel Study, and worktime control was not surveyed in the 2000-2008 Work and Health in Finnish Hospital Personnel Study. A dummy category was created for missing values in logistic models to avoid sample exclusion by the statistical software. In the statistical analysis of the register cohort, weekly working hours were retrieved from the registry data.

Statistical analysis

The distribution of baseline age, gender, physical inactivity, working hours, work time control, and having small children was examined separately in the survey and register cohorts. The difference between baseline characteristics according to work schedule was examined using chi-square tests and analysis of variance. Post hoc pairwise comparisons using Tukey's procedure for continuous variables and Bonferroni correction for categorical variables were performed.

The fixed-effects logistic model was used to examine the longitudinal dataset for associations between changes in work schedule and changes in physical inactivity during the survey period. Participants who exhibited changes in the outcome (physical inactivity) in at least two waves of the survey were considered informative and were included in the analysis. The longitudinal fixed effects model is advantageous because time-independent known and unknown confounders are eliminated when the intra-individual changes over time are examined (39). Therefore, the study participants served as their own controls. The survey cohort was stratified by gender and occupations to examine associations between different genders and occupational groups (blue-collar and white-collar). To control the time-variant confounders, we added weekly working hours, having small children, and worktime control to the adjusted models. To examine risk factors for physical inactivity among shift workers in the survey cohort (shift work with and without night shifts and fixed night workers, N=29 019), we examined associations between changes in physical inactivity and changes in having small children, worktime control, and working hours with fixed effects models. SAS 9.4 (SAS Institute, Cary, NC, USA) was used for the analyses. The significance level was set at $P<0.05$.

Results

According to the first survey available for each participant in the survey cohort, 77 250 (81.2%) employees were women and 15 488 (16.3%) were physically inactive. Shift workers with night shifts were younger than workers in the other groups (table 1). Shift workers without night shifts reported the highest percentage of physical inactivity (19.1%) of the four work schedule groups. The post hoc analysis revealed that physical inactivity, having small children, working hours, and worktime control scores differed significantly between workers with day work, shift work without night shifts, and shift work with night shifts. A higher percentage of workers with shift work without night shifts lacked vigorous physical activity than workers with other shift schedules. According to the crude longitudinal fixed effects logistic model, compared with day work (table 2), shift work with night shifts was negatively associated with physical inactivity [odds ratio (OR) 0.88, 95% confidence interval (CI) 0.79-0.98). In the adjusted model, the association remained significant (OR 0.89, 95% CI 0.80-0.99). After stratification by gender and occupation, the association was significant only among women (OR 0.85, 95% CI 0.76-0.96) and white-collar workers (OR 0.86, 95% CI 0.77-0.97). Among men, a positive association between shift work without night shifts and physical inactivity was observed (OR 1.38, 95% CI 1.09-1.74). Compared with day work, shift work with or without night shifts and fixed night work were not significantly associated with lack of vigorous physical activity.

In the register cohort, 24 165 (92.8%) employees were women and 4456 (17.1%) were physically inactive. Based on the adjusted model, a high percentage of night shifts was negatively associated with physical inactivity (OR 0.84, 95% CI 0.72-0.98) (table 3). The association was no longer significant when the study participants were restricted to shift workers (OR 0.87, 95% CI 0.73-1.03). Other objective working time characteristics were not associated with physical inactivity, and no working time characteristic was associated with lack of vigorous activity either.

Table 4 displays the OR of intra-individual changes in worktime control, working hours, and having small children for physical inactivity among shift workers. For worktime control variable components, control over time off was included in the models because it is more relevant for shift workers than control over daily hours. In the adjusted model, having small children remained significantly associated with physical inactivity in shift work (OR 1.47, 95% CI 1.32-1.65).

Discussion

Based on analysis of this extensive body of prospective data, this study determined that shift work with night shifts was associated with more physical activity, but the association is restricted to women and white-collar workers. Changes in objective working time characteristics were not associated with changes in physical inactivity among shift workers. Having small children was associated with physical inactivity among shift workers.

The finding that shift work with night shifts was associated with more leisure-time physical activity, especially light intensity activities, was consistent with a large-scale Dutch survey study (15) and two smaller studies (14, 16).

Findings from our objective registry data that night shifts were associated with more physical activity in the whole register cohort but not among shift workers implies that working night shifts, generally, rather than working a high percentage of night shifts affects physical activity. A study by Loef et al (15) suggested that shift workers slept fewer hours and therefore had more time for light physical activity. However, a recent study using the same FPS Study cohort discovered that shift work with night shifts was associated with longer sleep duration (40). We suggest that engaging in shift work with night shifts allows workers to utilize free daytime hours and free weekdays, and their attendant superior daylight hours, to engage in physical activities.

The association between shift work with night shifts and physical activity was significant only among women and white-collar workers. In general, men have longer working hours, more non-day shifts, and less recovery time than women, and this was observed also in Finland (41). It is thus possible that men have a higher need for recovery from shift work than women (42, 43). On the other hand, it has been reported that men tend to drive to work, whereas women walk or cycle more frequently (44, 45). It is possible that women performed more light-to-moderate intensity exercise during their commutes. A Japanese study also demonstrated that female shift workers managed to maintain healthy lifestyles more effectively compared with male shift workers (46). Therefore, female shift workers may compensatorily increase physical activity when they work night shifts. Our findings also indicated that blue-collar workers did not display changes in physical activity when they changed between day and shift work, probably because they had a consistently low level of leisure-time activity compared with white-collar workers (9).

In this study, objective variables of shift intensity were not significantly associated with physical activity, although they were associated with fatigue and sleep in another study with the same cohort (32). This finding indicates that changes in physical activity occur more slowly than changes in sleep and fatigue; therefore, longer exposure may be needed to bring about changes in physical activity. Leisure-time physical activity may also be more responsive to work schedule changes than to shift intensity changes, and intra-individual variation of these shift intensity variables over time were relatively small in our study sample. A cross-industry or cross-nation comparison with larger variations in shift intensity might yield significant findings.

Consistent with previous studies, we also observed lower worktime control among shift workers compared with day workers (27, 28). Nevertheless, low worktime control was not associated with physical inactivity among shift workers, but having small children was. This finding is consistent with earlier discoveries that physical activity levels are lower among parents of small children, especially mothers (47). In addition, work-family conflict has been reported to be associated with shift work more often than with regular day work (33, 48) and is associated with changing from shift work to day work (49). To encourage physical activity among shift workers and also to maintain the workforce, future studies should examine the barriers to engaging in physical activity among shift workers with young children.

A strength of this study is that it used an extensive longitudinal dataset that was collected over 17 years to examine the association between work schedule, working hour characteristics, and physical activity. The long follow-up period allowed us to investigate individual changes in health behavior along with changes in working schedules. The use of longitudinal fixed-effects models enabled us to minimize the selection bias that is commonly seen in shift work studies. Second, the use of objective data regarding working hours makes this study unique because it could analyze precise working hour information.

Nevertheless, this study has some limitations. First, physical activity was self-reported, rendering it vulnerable to participant interpretation and recall bias. In one study, workers were observed to over-report engaging in vigorous physical activities, especially workers with fatigue symptoms (50). Furthermore, shift workers who became ill during the follow-up tended to switch to day work (51) and became less physically active compared with the time before the illness. Therefore, the association between shift work and physical activity may have been overestimated in our study. Second, the study participants were Finnish workers from a female-dominated public sector with working conditions, including working hours and work-life balance, that could be more favorable than the work conditions in other sectors or countries (52). It is expected that in an industry or country with long working hours or high shift intensity, the association between shift work and physical activity may be different. The interpretation of the results of this study should thus be restricted to workplaces with normal working hours and societies with similar working times (53).

In conclusion, we discovered that changes in work schedule were slightly associated with changes in physical activity. The association depended on gender and occupation. Among women and white-collar workers, the shift work-related health risks are unlikely the result of decreased physical activity. On the contrary, shift workers may have elevated awareness of their health risks and may attempt to compensate for the health risks by increasing their physical activity. Nevertheless, shift workers with small children were found to be at higher risk of physical inactivity. Access to childcare services when parents work shifts, support for childcare from a spouse or other family members, and public resources that make engaging in physical activity easier for those with children would help promote physical activity among shift workers.

Acknowledgements

This paper was supported by the Finnish Academy (grant number: 323882), Ministry of Science and Technology, Taiwan (grant number: 108-2918-I-039-001 and MOST 107-2314-B-039-063-MY3), and NordForsk, the Nordic Program on Health and Welfare (grant number: 74809). The funders had no role in: study design; the collection, analysis, and interpretation of the data; the writing of the report; or the decision to submit the paper for publication.

Conflict of interest

The authors declare no conflicts of interest.

Sidebar

We combined objective working hour data with surveys on physical activity over 17 years. Compared with day work, shift work without night shifts was associated with physical inactivity among men, whereas shift work with night shifts was negatively associated with physical inactivity among women and white-collar workers. Having small children was a risk factor for physical inactivity among shift workers.

Refers to the following texts of the Journal: 2011;37(5):402-410 2012;38(6):590-599 2014;40(6):543-556 2015;41(3):268-279 2017;43(2):127-135 2018;44(3):265-273 2018;44(4):394-402 2019;45(4):376-385

Key terms: Finland; Finnish Public Sector Study; fixed effect; fixed-effects modeling; leisure-time physical activity; longitudinal study; physical activity; physical inactivity; shift work; shift worker; work schedule; working time

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/31788701

Additional material

Please note that there is additional material available belonging to this article on the Scandinavian Journal of Work, Environment &Health -website.

Correspondence to: Wan-Ju Cheng, MD, PhD, Department of Psychiatry, China Medical University Hospital, 2 Yude Road, Taichung, 40447, Taiwan. [E-mail: s871065@gmail.com]

Received for publication: 5 September 2019

References

Reference

1. Kecklund G, Axelsson J. Health consequences of shift work and insufficient sleep. BMJ 2016 Nov;355:i5210. https://doi. org/10.1136/bmj.i5210.

2. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT; Lancet Physical Activity Series Working Group. Effect of physical inactivity on major noncommunicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012 Jul;380(9838):21929. https://doi.org/10.1016/S0140-6736(12)61031-9.

3. Neil-Sztramko SE, Pahwa M, Demers PA, Gotay CC. Health-related interventions among night shift workers: a critical review of the literature. Scand J Work Environ Health 2014 Nov;40(6):543-56. https://doi.org/10.5271/sjweh.3445.

4. Flahr H, Brown WJ, Kolbe-Alexander TL. A systematic review of physical activity-based interventions in shift workers. Prev Med Rep 2018 Apr;10:323-31. https://doi. org/10.1016/j.pmedr.2018.04.004.

5. Lassen AD, Fagt S, Lennernäs M, Nyberg M, Haapalar I, Thorsen AV et al. The impact of worksite interventions promoting healthier food and/or physical activity habits among employees working 'around the clock' hours: a

systematic review. Food Nutr Res 2018 Aug;62. https://doi. org/10.29219/fnr.v62.1115.
6. Atkinson G, Davenne D. Relationships between sleep, physical activity and human health. Physiol Behav 2007 Feb;90(2-3):229-35. https://doi.org/10.1016/j. physbeh.2006.09.015
7. Pepłońska B, Burdelak W, Krysicka J, Bukowska A, Marcinkiewicz A, Sobala W et al. Night shift work and modifiable lifestyle factors. Int J Occup Med Environ Health 2014 Oct;27(5):693-706. https://doi.org/10.2478/s13382014-0298-0.
8. Bushnell PT, Colombi A, Caruso CC, Tak S. Work schedules and health behavior outcomes at a large manufacturer. Ind Health 2010;48(4):395-405. https://doi.org/10.2486/ indhealth.MSSW-03.
9. Vandelanotte C, Short C, Rockloff M, Di Millia L, Ronan K, Happell B et al. How do different occupational factors influence total, occupational, and leisure-time physical activity? J Phys Act Health 2015 Feb;12(2):200-7. https:// doi.org/10.1123/jpah.2013-0098.
10. Schneider S, Becker S. Prevalence of physical activity among the working population and correlation with workrelated factors: results from the first German National Health Survey. J Occup Health 2005 Sep;47(5):414-23. https://doi.org/10.1539/joh.47.414.
11. Buchvold HV, Pallesen S, Øyane NM, Bjorvatn B. Associations between night work and BMI, alcohol, smoking, caffeine and exercise-a cross-sectional study. BMC Public Health 2015 Nov;15:1112. https://doi. org/10.1186/s12889-015-2470-2.
12. Clark BK, Kolbe-Alexander TL, Duncan MJ, Brown W. Sitting Time, Physical Activity and Sleep by Work Type and Pattern-The Australian Longitudinal Study on Women's Health. Int J Environ Res Public Health 2017 Mar;14(3):14. https://doi.org/10.3390/ijerph14030290.
13. Tada Y, Kawano Y, Maeda I, Yoshizaki T, Sunami A, Yokoyama Y et al. Association of body mass index with lifestyle and rotating shift work in Japanese female nurses. Obesity (Silver Spring) 2014 Dec;22(12):2489-93.
14. Marqueze EC, Ulhôa MA, Castro Moreno CR. Leisure-time physical activity does not fully explain the higher body mass index in irregular-shift workers. Int Arch Occup Environ Health 2014 Apr;87(3):229-39. https://doi.org/10.1007/ s00420-013-0850-4.
15. Loef B, Hulsegge G, Wendel-Vos GC, Verschuren WM, Vermeulen RC, Bakker MF et al. Non-occupational physical activity levels of shift workers compared with non-shift workers. Occup Environ Med 2017 May;74(5):328-35. https://doi.org/10.1136/oemed-2016-103878.
16. Ma CC, Burchfiel CM, Fekedulegn D, Andrew ME, Charles LE, Gu JK et al. Association of shift work with physical activity among police officers: the Buffalo cardiometabolic occupational police stress study. J Occup Environ Med 2011 Sep;53(9): 1030-6. https://doi.org/10.1097/ JOM.0b013e31822589f9.
17. Bekkers MB, Koppes LL, Rodenburg W, van Steeg H, Proper KI. Relationship of night and shift work with weight change and lifestyle behaviors. J Occup Environ Med 2015 Apr;57(4):e37-44. https://doi.org/10.1097/ JOM.0000000000000426.
18. Wang XS, Travis RC, Reeves G, Green J, Allen NE, Key TJ et al. Characteristics of the Million Women Study participants who have and have not worked at night. Scand J Work Environ Health 2012 Nov;38(6):590-9. https://doi. org/10.5271/sjweh.3313.
19. Roskoden FC, Krüger J, Vogt LJ, Gärtner S, Hannich HJ, Steveling A et al. Physical Activity, Energy Expenditure, Nutritional Habits, Quality of Sleep and Stress Levels in Shift-Working Health Care Personnel. PLoS One 2017 Jan;12(1):e0169983. https://doi.org/10.1371/journal. pone.0169983.
20. Hulsegge G, Gupta N, Holtermann A, Jørgensen MB, Proper KI, van der Beek AJ. Shift workers have similar leisure-time physical activity levels as day workers but are more sedentary at work. Scand J Work Environ Health 2017 Mar;43(2): 127-35. https://doi.org/10.5271/sjweh.3614.
21. Loprinzi PD. The effects of shift work on free-living physical activity and sedentary behavior. Prev Med 2015 Jul;76:43-7. https://doi.org/10.1016/j.ypmed.2015.03.025.
22. Loef B, van der Beek AJ, Holtermann A, Hulsegge G, van Baarle D, Proper KI. Objectively measured physical activity of hospital shift workers. Scand J Work Environ Health 2018 May;44(3):265-73.

https://doi.org/10.5271/sjweh.3709.
23. Piirtola M, Kaprio J, Kujala UM, Heikkilä K, Koskenvuo M, Svedberg P et al. Association between education and future leisure-time physical inactivity: a study of Finnish twins over a 35-year follow-up. BMC Public Health 2016 Aug;16:720. https://doi.org/10.1186/s12889-016-3410-5.
24. Piirtola M, Kaprio J, Waller K, Heikkilä K, Koskenvuo M, Svedberg P et al. Leisure-time physical inactivity and association with body mass index: a Finnish Twin Study with a 35-year follow-up. Int J Epidemiol 2017 Feb;46(1):116-27. https://doi.org/10.1093/ije/dyw007.
25. Borodulin K, Harald K, Jousilahti P, Laatikainen T, Männistö S, Vartiainen E. Time trends in physical activity from 1982 to 2012 in Finland. Scand J Med Sci Sports 2016 Jan;26(1):93-100. https://doi.org/10.1111/sms.12401.
26. Knauth P. Innovative worktime arrangements. Scand J Work Environ Health 1998;24 Suppl 3:13-7.
27. Albrecht SC, Kecklund G, Tucker P, Leineweber C. Investigating the factorial structure and availability of work time control in a representative sample of the Swedish working population. Scand J Public Health 2016 May;44(3):320-8. https://doi.org/10.1177/1403494815618854.
28. Ala-Mursula L, Vahtera J, Linna A, Pentti J, Kivimäki M. Employee worktime control moderates the effects of job strain and effort-reward imbalance on sickness absence: the 10-town study. J Epidemiol Community Health 2005 Oct;59(10):851-7. https://doi.org/10.1136/ jech.2004.030924.
29. Vahtera J, Laine S, Virtanen M, Oksanen T, Koskinen A, Pentti J et al. Employee control over working times and risk of cause-specific disability pension: the Finnish Public Sector Study. Occup Environ Med 2010 Jul;67(7):479-85. https://doi.org/10.1136/oem.2008.045096
30. Härmä M, Koskinen A, Ropponen A, Puttonen S, Karhula K, Vahtera J et al. Validity of self-reported exposure to shift work. Occup Environ Med 2017 Mar;74(3):228-30. https:// doi.org/10.1136/oemed-2016-103902.
31. Härmä M, Ropponen A, Hakola T, Koskinen A, Vanttola P, Puttonen S et al. Developing register-based measures for assessment of working time patterns for epidemiologic studies. Scand J Work Environ Health 2015 May;41(3):26879. https://doi.org/10.5271/sjweh.3492.
32. Härmä M, Karhula K, Ropponen A, Puttonen S, Koskinen A, Ojajärvi A et al. Association of changes in work shifts and shift intensity with change in fatigue and disturbed sleep: a within-subject study. Scand J Work Environ Health 2018 Jul;44(4):394-402. https://doi.org/10.5271/sjweh.3730.
33. Karhula K, Koskinen A, Ojajärvi A, Ropponen A, Puttonen S, Kivimäki M et al. Are changes in objective working hour characteristics associated with changes in work-life conflict among hospital employees working shifts? A 7-year followup. Occup Environ Med 2018 Jun;75(6):407-11. https://doi. org/10.1136/oemed-2017-104785.
34. Virtanen M, Ervasti J, Head J, Oksanen T, Salo P, Pentti J et al. Lifestyle factors and risk of sickness absence from work: a multicohort study. Lancet Public Health 2018 Nov;3(11):e545-54. https://doi.org/10.1016/S24682667(18)30201-9.
35. Ervasti J, Airaksinen J, Pentti J, Vahtera J, Suominen S, Virtanen M et al. Does increasing physical activity reduce the excess risk of work disability among overweight individuals? Scand J Work Environ Health 2019 Jul;45(4):376-85. https://doi.org/10.5271/sjweh.3799.
36. Kujala UM, Kaprio J, Sarna S, Koskenvuo M. Relationship of leisure-time physical activity and mortality: the Finnish twin cohort. JAMA 1998 Feb;279(6):440-4. https://doi. org/10.1001/jama.279.6.440.
37. Ala-Mursula L, Vahtera J, Pentti J, Kivimäki M. Effect of employee worktime control on health: a prospective cohort study. Occup Environ Med 2004 Mar;61(3):254-61. https:// doi.org/10.1136/oem.2002.005983.
38. Statistics Finland. Classification of Occupations 2001. July 5, 2019]; Available from: http://www.stat.fi/meta/luokitukset/ ammatti/001-2001/index_en.html.
39. Gunasekara FI, Richardson K, Carter K, Blakely T. Fixed effects analysis of repeated measures data. Int J Epidemiol 2014 Feb;43(1):264-9. https://doi.org/10.1093/ije/dyt221.
40. Härmä M, Karhula K, Puttonen S, Ropponen A, Koskinen A, Ojajärvi A et al. Shift work with and without night work as a risk factor for fatigue and changes in sleep length: A cohort study with linkage to records on daily working hours. J Sleep Res 2019 Jun;28(3):e12658. https://doi.org/10.1111/ jsr.12658.

41. Official Statistics of Finland. Time use, Structure of Working Week 2009, O.S.o.F.O.T.u. [Available from: http://tilastokeskus.fi/til/akay/2009/07/akay_2009_07_2014-0416_tie_001_en.html], Editor. 2019: Helsinki, Finland.
42. Mohren DC, Jansen NW, Kant I. Need for recovery from work in relation to age: a prospective cohort study. Int Arch Occup Environ Health 2010 Jun;83(5):553-61. https://doi. org/10.1007/s00420-009-0491-9.
43. Jansen N, Kant I, van Amelsvoort L, Nijhuis F, van den Brandt P. Need for recovery from work: evaluating shortterm effects of working hours, patterns and schedules. Ergonomics 2003 Jun;46(7):664-80. https://doi.org/10.108 0/0014013031000085662.
44. Xu CX, Zhu HH, Fang L, Hu RY, Wang H, Liang MB et al. Gender disparity in the associations of overweight/obesity with occupational activity, transport to/from work, leisuretime physical activity, and leisure-time spent sitting in working adults: A cross-sectional study. J Epidemiol 2017 Sep;27(9):401-7. https://doi.org/10.1016/jje.2016.08.019.
45. Audrey S, Procter S, Cooper AR. The contribution of walking to work to adult physical activity levels: a cross sectional study. Int J Behav Nutr Phys Act 2014 Mar;11(1):37. https://doi.org/10.1186/1479-5868-11-37.
46. Kaneko SY, Maeda T, Sasaki A, Sato A, Tanaka K, Kobayashi T et al. Changes in health habits of female shift workers. J Occup Health 2004 May;46(3): 192-8. https://doi. org/10.1539/joh.46.192.
47. Adamo KB, Langlois KA, Brett KE, Colley RC. Young children and parental physical activity levels: findings from the Canadian health measures survey. Am J Prev Med 2012 Aug;43(2): 168-75. https://doi.org/10.1016j. amepre.2012.02.032.
48. Karhula K, Puttonen S, Ropponen A, Koskinen A, Ojajärvi A, Kivimäki M et al. Objective working hour characteristics and work-life conflict among hospital employees in the Finnish public sector study. Chronobiol Int 2017;34(7):87685. https://doi.org/10.1080/07420528.2017.1329206.
49. Jansen NW, Mohren DC, van Amelsvoort LG, Janssen N, Kant I. Changes in working time arrangements over time as a consequence of work-family conflict. Chronobiol Int 2010 Jul;27(5): 1045-61. https://doi.org/10.3109/07420528.2010. 489874.
50. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. Int J Behav Nutr Phys Act 2008 Nov;5:56. https://doi.org/10.1186/1479-5868-5-56.
51 . Driesen K, Jansen NW, van Amelsvoort LG, Kant I. The mutual relationship between shift work and depressive complaints-a prospective cohort study. Scand J Work Environ Health 2011 Sep;37(5):402-10. https://doi. org/10.5271/sjweh.3158.
52. Puig-Barrachina V, Vanroelen C, Vives A, Martínez JM, Muntaner C, Levecque K et al. Measuring employment precariousness in the European Working Conditions Survey: the social distribution in Europe. Work 2014;49(1):143-61.
53. EuroFound and International Labour Organization. Working conditions in a global perspective, ed. EuroFound. 2019, Geneva: Publication Office of the European Union, Luxembourg, and International Labour Organization.

DETAILS

Subject:	Socioeconomic factors; Shift work; Working conditions; Workers; Risk factors; Chronic illnesses; Children; Night shifts; Public sector; Working hours; Risk analysis; Nurses; Longitudinal studies; Confidence intervals; Employees; Metabolic disorders; Health risk assessment; Nighttime; Schedules; Health risks; Correlation analysis
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46

Issue:	3
Pages:	293-301,293A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3868
ProQuest document ID:	2406985134
Document URL:	https://www.proquest.com/scholarly-journals/shift-work-physical-inactivity-findings-finnish/docview/2406985134/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2020-05-27
Database:	Public Health Database

Do gender and psychosocial job stressors modify the relationship between disability and sickness absence: An investigation using 12 waves of a longitudinal cohort

Milner, A; Aitken, Z; Byars, S; Butterworth, P; Kavanagh, A [1] [1] Disability and Health Unit, Centre for Health Equity, Melbourne School of Population and Global Health, the University of Melbourne, Victoria 3010, Australia

ABSTRACT (ENGLISH)

Objectives A considerable proportion of the working population reports a disability. These workers may be at risk of adverse outcomes, including longer periods of sickness absence. This study examined the causal effect of disability on sickness absence and the role of psychosocial job stressors and gender as effect modifiers. Methods Data on paid and unpaid sick leave, disability (yes/no) and psychosocial job stressors were available from 2005 to 2017 from the Household, Income and Labour Dynamics in Australia (HILDA) survey. Negative binomial models were used to model the rate of sickness absence in a year. Results In the random effects model, workers with disability had 1.20 greater rate of sickness absence in a year [95% confidence interval (CI) 1.17-1.23, P<0.001] after adjustment for confounders. The rate was slightly lower in the fixed effects model. There was evidence of multiplicative interaction of the effect by gender and job control. The effect of disability on sickness absence was greater among men than women, and higher for people with low job control compared to those with high job control. Conclusions There is a need for more research about the factors that can reduce sickness leave among workers with disabilities.

FULL TEXT

Headnote

Objectives A considerable proportion of the working population reports a disability. These workers may be at risk of adverse outcomes, including longer periods of sickness absence. This study examined the causal effect of disability on sickness absence and the role of psychosocial job stressors and gender as effect modifiers.
Methods Data on paid and unpaid sick leave, disability (yes/no) and psychosocial job stressors were available from 2005 to 2017 from the Household, Income and Labour Dynamics in Australia (HILDA) survey. Negative binomial models were used to model the rate of sickness absence in a year.
Results In the random effects model, workers with disability had 1.20 greater rate of sickness absence in a year [95% confidence interval (CI) 1.17-1.23, P<0.001] after adjustment for confounders. The rate was slightly lower in the fixed effects model. There was evidence of multiplicative interaction of the effect by gender and job control. The effect of disability on sickness absence was greater among men than women, and higher for people with low job control compared to those with high job control.
Conclusions There is a need for more research about the factors that can reduce sickness leave among workers with disabilities.
Key term job control; HILDA survey; sick leave; sickness leave; unpaid leave; working condition.
Globally, the prevalence of workers with disabilities is substantial (1) and is projected to increase in many countries worldwide (2). Disability is a complex construct. The most commonly accepted definition disability is based on the International Classification of Functioning, Disability and Health, where disability is an umbrella terms that includes impairments (eg, loss of a limb), limitations (eg, unable to dress independently) and participation restrictions (eg, unable to go to community events) (3). Although statistics vary between countries, evidence suggests that 50-80% of people with disabilities are employed across the OECD (4). In Australia, 53% of people with a disability were employed in 2015 (5). Research suggests that people with disabilities disproportionality experience poorer quality working experiences (6), including being underemployed (7) and reporting unfair pay for the work they do (8). Workers with disabilities are more likely to exit into "not in the labour force" (NILF) and unemployment (9) than those without disabilities. Workers with disabilities may also have a high rate of sickness absence. The rationale for this argument stems from the substantial amount of research demonstrating a relationship between chronic mental or

physical health problems and sickness absence (10, 11). In particular, people with mental health disorders have been found to have twice the odds of sickness absence (11), while those who suffer from poor physical health and experience pain and injury (12) are at greater risk of taking longer periods of sickness absence.

Gender also appears to be an important factor for consideration in sickness absence (13), which may be connected to greater ill-health burden among women. It is also important to consider that females are also more likely to be primary carers for children or other dependents (14). Thus, females may be taking sickness absence in order to care for others (15). Past research also suggests that workplace-related factors need to be addressed in sickness absence interventions (16). This is because workplace-related factors such as psychosocial job stressors (eg, low job control and high job demands) have been shown to be associated with increased risk of sickness absence (17, 18). However, there is lack of quantitative research on whether targeting these stressors could lead to a reduction in sickness absence among workers with disabilities. Similarly, there is a lack of research on whether the gendered dynamics of sickness absence observed in previous studies are also apparent among workers with disabilities. Understanding the drivers of sickness absence among at-risks groups such as those with a disability will be of key interest to government and employers, particularly since there has been considerable investment in disability employment programs in many countries around the world (19). In the UK, the cost of sickness absence was estimated to be £9 billion annually in terms of lost productivity, with costs thought to be similar in other OECD countries (20). These costs extend beyond the workplace as sickness absence is predictive of exiting from the labour market onto disability pension (21-23), and thus has direct costs for the government. There are also community and individual costs as sickness absence is strongly correlated with a range of poor health outcomes at a population level, including mortality, depression, and hypertension (24).

The aim of the current paper is to examine the relationship between disability and sickness absence in Australia's working-age population, as well as examining important factors that may modify this association. In particular, we will examine whether being exposed to psychosocial job stressors (eg, low job control, high job demands, low job security, and low fairness of pay) results in greater sickness absence among persons with disabilities. We will also examine the role of gender as an effect modifier of the relationship between disability and sickness absence based on previous research demonstrating that sickness absence is a highly-gendered experience.

Methods

Data source

The Household, Income and Labour Dynamics in Australia (HILDA) survey is a longitudinal, nationally representative study of households established in 2001. It collects detailed information annually from over 13 000 individuals within over 7000 households (25). The initial survey wave began with a large national probability sample of households occupying private dwellings (25). The survey covers a range of dimensions including social, demographic, health and economic conditions using a combination of face-to-face interviews with trained interviewers and a self-completion questionnaire. The response rate for wave 1 was 66% (25). Interviews were sought in later waves with all persons in sampled households who turned 15 years of age. Additional persons have been added to the sample as a result of changes in household composition. Inclusion of these new households is the main way the HILDA survey maintains sample representativeness. A top-up sample of 2000 people was added to the survey in 2011 allowing better representation of the Australian population using the same methodology as the original sample (ie, a three-stage area-based design) (26). The response rates for the HILDA survey are >90% for respondents who have continued in the survey and >70% for new respondents being invited into the study (25). Those who were eligible for the study were working age people who had been employed continuously for >3 consecutive waves of HILDA. Only these consecutive waves (>3) were included in the analysis. As a sensitivity analysis and to test for consistency, we assessed results restricting to workers who reported their employer provided paid sick leave. The flow chart into the study can be seen in figure 1.

The Australian Government Department of Social Services Access provided access to HILDA, and the research conforms to the principles embodied in the Declaration of Helsinki.

Outcome

The primary outcome was a self-reported measure of days of sickness absence in the 12 months prior to their interview and following the last HILDA survey. This was ascertained through two questions: one on the number of days participants spent on paid sick leave in the last 12 months, and the other asking about days of unpaid leave in the last 12 months. Days of paid and unpaid sick leave were summed and used to calculate an incidence rate (number of sick days in a year/total number of days in a year). The Australian National Employment standards stipulate that permanent employees have a >10 paid sick leave days per year. Recognizing that people with disabilities may require more sick leave than the paid sick leave provided by the employer, we also considered days of unpaid leave within a 12-month period. Paid and unpaid sick leave were summed. Information on paid and unpaid sickness absence is available in HILDA from 2005 onwards.

Exposure

Disability was determined from the following survey question "...do you have any long-term health condition, impairment or disability that restricts you in your everyday activities, and has lasted or is likely to last, for six months or more?". Specific examples of long-term conditions were shown, such as limited use of fingers or arms, long-term psychological problems, or problems with eyesight that could not be corrected with glasses or contact lenses. Disability was classified as a binary variable (yes/no). As a sensitivity analysis (discussed below), we conducted further analysis on individuals who acquired a disability (incident disability). This included those who had at least two consecutive waves of disability preceded by >2 consecutive waves without disability. We also considered a time-invariant definition of disability where we had three groups of disability: consistently reported in all contributed waves of HILDA, time varying reported disability (reported in some contributed waves and not others), and no reported disability in any contributed waves.

Effect modifiers

Gender (male or female) was collected from 2001 onwards. We considered four main psychosocial job stressors as possible effect modifiers. These were: job control (three items), job demands and complexity (three items), job insecurity (three items), and fairness of pay. All scales were based on a likert scale, where 1 was "strongly disagree" and 7 was "strongly agree". Scale reliabilities for these variables are based on analyses of all waves of data. Job control included: "I have a lot of freedom to decide how I do my own work"; "I have a lot of say about what happens on my job", and; "I have a lot of freedom to decide when I do my work". The scale reliability coefficient for these three items was 0.82. Job demands and complexity included: "My job is complex and difficult"; "My job often requires me to learn new skills", and; "I use many of my skills and abilities in my current job". The scale reliability coefficient was 0.72. Job insecurity included: "I have a secure future in my job"; the company I work for will still be in business 5 years from now", and; "I worry about the future of my job" (which was reverse coded). The scale reliability coefficient was 0.67. Fairness of pay was calculated from one item: "I get paid fairly for the things I do in my job". We dichotomized each total job stressor scale at the 75th percentile to create a binary variable representing those exposed versus non-exposed to each job stressor. We used the most-adverse quartile dichotomization based on previous predictive validation of these measures in relation to health outcomes (27).

Confounders

Our confounders included age (15-24, 25-29, 30-34, 35-44, 45-54 and 55-64 years), education [less than Year 12 (high school), Year 12, diploma or certificate, bachelors degree or higher], household structure (couple without children, couple with children, lone parent with children, lone person, and other), weekly household income (equivalized), employment arrangement (permanent, casual, fixed term, and self-employed) and a three-level variable capturing occupational skill level defined using the Australian and New Zealand Standard Classification of Occupations: low (eg, sales workers, machinery operators and drivers, laborers), medium (eg, technicians and trade workers, community and personal services workers, clerical and administrative workers), and high (managers, professionals) (28). Gender was included as a confounder in main effects models, before being assessed as an effect modifier.

Analysis

At the first stage of analysis, we looked at the descriptive associations (means, frequencies) of disability and

sickness absence by the effect modifiers.
We then used negative binominal random and fixed effects (FE) regression to model the relationship between sickness absence and disability as there was evidence of over-dispersion in the outcome variable. Random effects (RE) models model within and between individual variation while RE models only model within individual variation. The coefficients produced from RE models represent a weighted average of the estimates due to the within and between person effects. In our case, the RE coefficients for the effects of disability on sickness absence represent a combination of the relationship observed when we look at disability and sickness absence across (or between) different people and the relationship occurring within persons (eg, changes in disability status and days of sickness absence in a year within the same person over time).
It was not possible to fit these fixed effect models with negative binominal outcomes panel models in commercial statistical packages [such as Stata/SE 15.0 for Mac (64-bit Intel) (StataCorp, College Station, TX, USA], therefore we replicated the FE approach manually by generating the difference scores (ie, deviation from each individuals' mean score for all time-varying covariates) and implemented the model as a RE model. However, this approach estimates within-person effects only because all between-person differences are removed due to lack of variation in subject-specific means). These are referred to as FE models in the paper. Coefficients were transformed into incident rate ratios to ease interpretation.
The possibility that the relationship between disability and sickness absence differed for males and females was assessed by examining the statistical significance of the interaction terms and the results of the likelihood ratio test. This was tested in a negative binomial model. The same approach was used to assess if the relationship differed depending on reporting of psychosocial job stressors. We then used the approach to presenting effect modification results recommended by Knol &VanderWeele (29) and computed effect measure modification on the additive and multiplicative scales. Using this approach, additive effect measure modification was assessed by estimating the relative excess risk of interaction (RERI), which occurs when the effect of the exposure and the effect modifier considered together exceeds the sum of individual effects of the exposure and effect modifier.
Additive interaction term = pL1 - p10 - p01 - p00
Where p11 refers to the probability of the outcome for the exposed when the effect modifier is present.
The multiplicative effect measure modification is measured on the ratio scale and is estimated from the interaction term in the model. It represents the extent to which, on the ratio scale, the effect of the exposure and the effect modifier exceeds the product of the effects considered separately (30).
(ProQuest: ... denotes formula omitted.)
Additive effect measure modification is particularly useful when estimating the absolute benefit of interventions on the effect modifier of interest (30).
As both disability and psychosocial job stressors were time varying, a participant could change on one or both of these and still be included in the coefficient for this term. Because of this, we conducted an additional analysis to assess possible differences when we did not allow disability (our exposure) to vary. To do this, we constructed three groups (consistently reported disability, disability reported in some waves and not other and no disability) and this three-level variable was included and modelled in relation to changes in psychosocial job stressors and changes in sickness absence. As a sensitivity analysis, we calculated marginal effects (ie, taking the effects of the log scale) to understand the absolute effect of a given point increase in sickness absence in relation to a point change in the effect modifiers within strata of disability. As noted above, we considered a further sensitivity analysis restricted to workers who reported that their employers provided them with paid sick leave. All analyses were performed using Stata, version 15.1.
Results
The mean days of sickness absence was higher for people who reported a disability [5.73, standard deviation (SD) 11.41] compared to people who did not report a disability (mean 4.05, SD 7.53). Table 1 also shows the mean days of sickness absence in relation to the effect modifiers in the analytic sample. Females generally had higher sickness absence than men. Workers with lower control and lower reported fairness of pay had more sickness absence than

those with higher control. Results are more mixed for job demands and security, as those with low security and demands reported slightly more days of sickness absence in a year. A description of the analytic sample can be seen in table 2.

Results of the negative binomial models can be seen in table 3. These show that in both the RE [risk ratio (RR) 1.20, 95% CI 1.17-1.23, P<0.001] and FE (RR 1.16, 95% CI 1.14-1.19, P<0.001) models, disability was associated with a greater number of sickness absence in a year after adjustment (eg, there was a 1.20 and 1.16 times greater rate of sickness absence, respectively, when a person reported a disability). Results were also consistent when we tested a model restricting the sample to people who had acquired a disability (RE model RR 1.27, 95% CI 1.21-1.34, P<0.001; FE model RR 1.26, 95% CI 1.19- 1.34, P<0.001).

Results of the interaction tests using the RE model showed that only gender and job control were significant effect modifiers (both related to the interaction terms in the model and also the likelihood ratio tests). Results of these two models can be seen in table 4. There was a negative multiplicative (but not additive) interaction between disability and gender. As can be seen, there is a greater difference in sickness absence between men with a disability compared to those without (RR 1.24, 95% CI 1.21-1.28) than between women with and without a disability (RR 1.17, 95% CI 1.14-1.21). This was also seen in the marginal effects model which also estimates absolute differences (supplementary material, www.sjweh.fi/ show_abstract.php?abstract_id=3865, table S1).

Workers with disability who also had low control had a rate of sickness absence 1.43 times greater (95% 1.38-1.48) than workers with high control and no disability. Low control also had a slightly higher relative effect on sickness absence for people with disability (RR 1.19, 95% CI 1.15-1.24) compared to those without (RR 1.15, 95% CI 1.12-1.17). These results were also apparent when we assessed the marginal effects model (supplementary table S1), in analyses where disability was held constant (supplementary table S2), and also when we restricted analysis to those who had an entitlement to sick leave (supplementary table S3).

Discussion

The results of this study indicate that psychosocial working conditions, such as low job control, influence the likelihood of taking sickness absence, both among people with and without disabilities. Our research also highlights the role of gender in relation to sickness absence. Reporting a disability (including the acquisition of disability) was associated with 1.2 times greater rate of sickness absence for a person compared to when they did not report a disability.

Our findings indicate that workers with disabilities take more sickness leave than those who do not have disabilities, which is an unsurprising finding given the literature we cite above. However, as an advance on previous research, we demonstrate within-persons changes in sickness absence in relation to the presence of a disability. This indicates the likely causal effect of disability on sickness absence after controlling for other time varying and invariant factors. Furthermore this effect was still evident when we restricted the sample to people who acquired a new disability. An obvious reason for these results is connected to a worsening of health conditions (10, 11). However, there are a range of factors that may influence sickness absence outside an individual's health. In particular, discrimination, stigma and bullying have been reported to be elevated among employed people with disabilities compared to those without disabilities (31). Previous research has shown a link between the experience of these types of adverse workplace experiences and greater likelihood of sickness absence (32, 33, 34). Hence, people with disabilities may be more exposed to stressors such as discrimination and bullying in workplace settings, and these may contribute to greater likelihood of taking sickness absence.

Another pertinent factor is low job control, which we found was predictive of sickness absence. We found that this was especially important to people with a disability (ie, there was a 1.24 times greater rate of taking sickness absence among people with disabilities experiencing low control compared to people with disabilities who reported high job control). There is a considerable amount of research demonstrating the importance of job control as both a determinant of sickness absence (34) and other health outcomes (35). Hence, we would suggest that providing workers with disabilities a greater amount of control of where, how, and when they work might be a useful way of addressing sickness absence. This may include allowing people the flexibility of working from home for a proportion of their working time, as well as providing some flexibility over what they are doing within their working day.

Our results also highlight the role of gender as a factor when considering the relationship between disability and sickness absence. Confirming previous research, we found that women were more likely to take sickness absence leave than men (13). However, results shifted once we considered the role of disability. We found that males with disabilities were more likely to take sickness absence than males without disabilities, and this difference was greater on the multiplicative scale than what we found for women. The different working life of men and women must be acknowledged here. In general, men are less likely to have periods out of the workforce (36). Men are also less likely to take sickness absence (18). In converse, the working life of women may be more disrupted as, in general, women are disproportionately responsible for looking after dependents and have other domestic responsibilities (36). On the basis of this, it is possible that disability has a greater impact on the working life of men leading to a stronger impact on sickness absence. This difference may be less obvious for women who are already likely to be more likely to take sick leave than men. However, the relative size of effect is small and so it would be premature to base reforms on these findings. These findings need further investigation in other datasets.

One of the first limitations of this research concerns the conceptual and methodological difficulty in separating disability from sickness absence. In this study, we attempted to address this through careful research design, such as using different definitions of disability and using FE modelling approaches. The disability acquisition analysis we conducted demonstrated an effect on sickness absence following disability onset. We also examined the impact of disability after this was held constant within a person. Regardless of these methodological approaches, we acknowledge that this is still a limitation, both conceptually and methodologically. Notwithstanding, there is a growing number of studies demonstrating the effect of employment conditions on the health of people with disabilities (eg, 37, 38). Hence, we would argue that our results are still important and have validity. It is also important to acknowledge likely differences based on the severity and type of impairment a person has, which we did not have the power to examine in this analysis. Other limitations are related to the fact that the data was self-reported, hence there is the possibility of misclassification bias. In saying this, we attempted to control for this by using a FE model to contrast within-person differences across the comparison groups. A FE model does this by holding stable factors constant, hence a person is able to act as their own control. There are many other important psychosocial aspects of the work environment that were not included in HILDA (eg, social support and bullying at work) that could also influence the relationship between disability and sickness absence. Further while classification of these psychosocial job stressors is based on previous research (27) and the use of relative measures (eg, upper quartile) is common (eg, relative poverty), future research should examine whether critical points can be identified so that absolute measures can be used (39).

In stating these limitations, there were also several strengths in this study. This included the ability to examine within-person effects controlling for time-invariant confounders that may have otherwise biased results. Further, we were able to include the entire spectrum of the employed population as we considered both paid and unpaid leave from work. This is particularly important in Australia as casual and self-employed persons do not usually have entitlement to paid sick leave.

In conclusion, this study highlights the role of both individual (eg, gender) and work-related (eg, job control) factors on the relationship between disability and sickness absence. From a prevention perspective, we would suggest that allowing people greater ability to have control of where, how and, when they work may be a way to address sickness absence. This might be particularly important for people with disabilities, especially given increased governmental emphasis on improving employment of people with disabilities internationally (19). There is also some evidence to suggest the role of clinical support and graded activities (eg, slow integration back into work) as a way to reduce sickness absence (16), although more research on intervention and prevention of sickness absence is needed.

Acknowledgments

We honour the memory of Associate Professor Allison Milner whose intellect and drive to do rigorous research that improves the health of disadvantaged people continues to inspire us. This paper uses unit record data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. HILDA was initiated and is funded by the

Australian Government Department of Social Services DSS and managed by the Melbourne Institute of Applied Economic and Social Research Melbourne Institute. The findings and views reported in this paper, however, are those of the author and should not be attributed to either DSS or the Melbourne Institute. The data used in this paper was extracted using the Add-On Package PanelWhiz for Stata. PanelWhiz (www.PanelWhiz.eu) was written by Dr. John P. Haisken-DeNew (john@PanelWhiz.eu).

Financial support

This work was supported by a Victorian Health and Medical Research Fellowship (to AM), NHMRC Partnership Project (APP1151843 to AM and AK), and NHMRC Centre for Research Excellence (APP1n6385 to AK and AM).

Conflict of interest

The authors declare no conflicts of interest.

Sidebar

This study reports that workers with disabilities may be more likely to take sickness absence. Gender and job control are important considerations in understanding these absences. Modifying working conditions may therefore reduce the likelihood of workers with disabilities taking sickness absence.

Milner A, Aitken Z, Byars S, Butterworth P, Kavanagh A. Do gender and psychosocial job stressors modify the relationship between disability and sickness absence: An investigation using 12 waves of a longitudinal cohort. Scand J Work Environ Health. 2020;46(3):302-310. doi:10.5271/sjweh.3865

Correspondence to: Professor Anne Kavanagh, Disability and Health Unit, Centre for Health Equity, Melbourne School of Population and Global Health, the University of Melbourne, Victoria 3010, Australia. [E-mail: a.kavanagh@unimelb.edu.au]

Received for publication: 14 July 2019

Footnote

1 Centre for Health Equity, Melbourne School Population and Global Health, The University of Melbourne, Victoria 3010 Australia

2 Melbourne Disability Institute, The University of Melbourne, Victoria 3010 Australia

3 Centre for Research on Ageing, Health and Wellbeing, Research School of Population Health, Australian National University, Canberra, ACT, 2600 Australia

4 Melbourne Institute of Applied Economic and Social Research, University of Melbourne, Victoria, 3010 Australia

* Sadly, Professor Allison Milner died tragically on 12 August 2019 after this paper was submitted for publication.

References

References

1. Blekesaune M. Have some European countries been more successful at employing disabled people than others? ISER Working Paper Series 2007; No. 2007-23.

2. WHO. World report on disability. Geneva, Switzerland: World Health Organization; 2011.

3. International Classification of Functioning. Disability and Health: ICF. Geneva, Switzerland: World Health Organization (WHO); 2001.

4. OECD. Sickness, Disability and Work: Breaking the Barriers. [electronic resource]: A Synthesis of Findings across OECD Countries. Paris: OECD Publishing; 2010.

5. Disability AB. Ageing and Carers, Australia: Summary of Findings, 2015. Cat. No. 4430.0. Canberra: Australian Bureau of Statistics; 2016.

6. LaMontagne AD, Krnjacki L, Milner A, Butterworth P, Kavanagh A. Psychosocial job quality in a national sample of working Australians: A comparison of persons working with versus without disability. SSM Popul Health 2016 Mar;2:175-81. https://doi.org/10.1016/j. ssmph.2016.03.001.

7. Milner A, King TL, LaMontagne AD, Aitken Z, Petrie D, Kavanagh AM. Underemployment and its impacts on mental health among those with disabilities: evidence from the HILDA cohort. J Epidemiol Community Health 2017 Dec;71(12):1198-202.

8. Milner A, Aitken Z, Krnjacki L, Bentley R, Blakely T, LaMontagne AD et al. Perceived fairness of pay among

people with and without disabilities: a propensity score matched analysis of working Australians. Scand J Work Environ Health 2015 Sep;41(5):451-9. https://doi. org/10.5271/sjweh.3515.
9. Milner A, Taouk Y, Disney G, Aitken Z, Rachele J, Kavanagh A. Employment predictors of exit from work among workers with disabilities: A survival analysis from the household income labour dynamics in Australia survey. PLoS One 2018 Dec;13(12):e0208334. https://doi. org/10.1371/journal.pone.0208334.
10. de Vries H, Fishta A, Weikert B, Rodriguez Sanchez A, Wegewitz U. Determinants of Sickness Absence and Return to Work Among Employees with Common Mental Disorders: A Scoping Review. J Occup Rehabil 2018 Sep;28(3):393-417. https://doi.org/10.1007/s10926-0179730-1.
11. Duijts SF, Kant I, Swaen GM, van den Brandt PA, Zeegers MP. A meta-analysis of observational studies identifies predictors of sickness absence. J Clin Epidemiol 2007 Nov;60(11):1105-15. https://doi.org/10.1016/j. jclinepi.2007.04.008.
12. Lötters F, Burdorf A. Prognostic factors for duration of sickness absence due to musculoskeletal disorders. Clin J Pain 2006 Feb;22(2):212-21. https://doi.org/10.1097/01. ajp.0000154047.30155.72.
13. Laaksonen M, Martikainen P, Rahkonen O, Lahelma E. Explanations for gender differences in sickness absence: evidence from middle-aged municipal employees from Finland. Occup Environ Med 2008 May;65(5):325-30. https://doi.org/10.1136/oem.2007.033910.
14. Bianchi SM, Sayer LC, Milkie MA, Robinson JP. Housework: Who Did, Does or Will Do It, and How Much Does It Matter? Soc Forces 2012 Sep;91(1):55-63. https:// doi.org/10.1093/sf/sos120.
15. Risa AE, Bratberg E, Dahl SÅ. 'The Double Burden': Do Combinations of Career and Family Obligations Increase Sickness Absence among Women? Eur Sociol Rev 2002; 18(2):233-49. https://doi.org/10.1093/esr/18.2.233.
16. Odeen M, Magnussen LH, Maeland S, Larun L, Eriksen HR, Tveito TH. Systematic review of active workplace interventions to reduce sickness absence. Occup Med (Lond) 2013 Jan;63(1):7-16. https://doi.org/10.1093/ occmed/kqs198.
17. Niedhammer I, Bugel I, Goldberg M, Leclerc A, Guéguen A. Psychosocial factors at work and sickness absence in the Gazel cohort: a prospective study. Occup Environ Med 1998 Nov;55(11):735-41. https://doi.org/10.1136/oem.55.11.735.
18. Milner A, Butterworth P, Bentley R, Kavanagh AM, LaMontagne AD. Sickness absence and psychosocial job quality: an analysis from a longitudinal survey of working Australians, 2005-2012. Am J Epidemiol 2015 May;181(10):781-8. https://doi.org/10.1093/aje/kwu355.
19. OECD. Transforming Disability into Ability. [electronic resource]: Policies to Promote Work and Income Security for Disabled People. Paris: OECD Publishing; 2003.
20. Taimela S, Justén S, Aronen P, Sintonen H, Läärä E, Malmivaara A et al. An occupational health intervention programme for workers at high risk for sickness absence. Cost effectiveness analysis based on a randomised controlled trial. Occup Environ Med 2008 Apr;65(4):242-8. https://doi.org/10.1136/oem.2007.033167.
21. van Rijn RM, Robroek SJ, Brouwer S, Burdorf A. Influence of poor health on exit from paid employment: a systematic review. Occup Environ Med 2014 Apr;71(4):295-301. https://doi.org/10.n36/oemed-2013-m1591.
22. Gjesdal S, Bratberg E. Diagnosis and duration of sickness absence as predictors for disability pension: results from a three-year, multi-register based· and prospective study. Scand J Public Health 2003;31(4):246-54. https://doi. org/10.1080/14034940210165154.
23. Kivimäki M, Forma P, Wikström J, Halmeenmäki T, Pentti J, Elovainio M et al. Sickness absence as a risk marker of future disability pension: the 10-town study. J Epidemiol Community Health 2004 Aug;58(8):710-1. https://doi. org/10.1136/jech.2003.015842.
24. Kivimäki M, Head J, Ferrie JE, Singh-Manoux A, Westerlund H, Vahtera J et al. Sickness absence as a prognostic marker for common chronic conditions: analysis of mortality in the GAZEL study. Occup Environ Med 2008 Dec;65(12):820-6. https://doi.org/10.1136/oem.2007.038398.
25. Wilkins R. Families, Incomes and Jobs, Volume 8: A Statistical Report on Waves 1 to 10 of the Household,

Income and Labour Dynamics in Australia Survey. Melbourne: Melbourne Institute of Applied Economic and Social Research; 2013.
26. Watson N. Methodology for the HILDA top-up sample. HILDA Project Technical Paper Series No 1/11. Melbourne: Melbourne Institute of Applied Economic and Social Research; 2011.
27. Butterworth P, Leach LS, Strazdins L, Olesen SC, Rodgers B, Broom DH. The psychosocial quality of work determines whether employment has benefits for mental health: results from a longitudinal national household panel survey. Occup Environ Med 2011 Nov;68(11):806-12. https://doi. org/10.1136/oem.2010.059030.
28. Australian Bureau of Statistics. (2016). ANZSCO- Australian and New Zealand Standard Classification of Occupations, 1st ed.; Australian Bureau of Statistics: Canberra, Australia, 2016.
29. Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. Int J Epidemiol 2012 Apr;41(2):514-20. https://doi.org/10.1093/ ije/dyr218.
30. VanderWeele TJ, Knol MJ. A Tutorial on Interaction. Epidemiol Methods 2014;3 (1):33-72. https://doi. org/10.1515/em-2013-0005.
31 . Fevre R, Robinson A, Lewis D, Jones T. The ill-treatment of employees with disabilities in British workplaces. J Work. Employ Soc. 2013;27(2):288-307. https://doi. org/10.1177/0950017012460311.
32. Mundbjerg Eriksen TL, Hogh A, Hansen ÅM. Long-term consequences of workplace bullying on sickness absence. Labour Econ 2016;43:129-50. https://doi.org/10.1016/j. labeco.2016.06.008.
33. Nielsen MB, Indregard AM, Øverland S. Workplace bullying and sickness absence: a systematic review and meta-analysis of the research literature. Scand J Work Environ Health 2016 Sep;42(5):359-70. https://doi.org/10.5271/sjweh.3579.
34. Duijts SF, Kant I, Swaen GM, van den Brandt PA, Zeegers MP. A meta-analysis of observational studies identifies predictors of sickness absence. J Clin Epidemiol 2007 Nov;60(11):1105-15. https://doi.org/10.1016/j. jclinepi.2007.04.008.
35. Harvey SB, Modini M, Joyce S, Milligan-Saville JS, Tan L, Mykletun A et al. Can work make you mentally ill? A systematic meta-review of work-related risk factors for common mental health problems. Occup Environ Med 2017 Mar;74(4):301-10. https://doi.org/10.1136/ oemed-2016-104015.
36. Milner A, Scovelle AJ, King TL, Marck CH, McAllister A, Kavanagh AM, et al. Gendered Working Environments as a Determinant of Mental Health Inequalities: A Protocol for a Systematic Review. Int J Environ Res Public Health. 2019;16(7). P11:E1169.
37. Milner A, Krnjacki L, Butterworth P, Kavanagh A, LaMontagne AD. Does disability status modify the association between psychosocial job quality and mental health? A longitudinal fixed-effects analysis. Soc Sci Med 2015 Nov;144:104-11. https://doi.org/10.1016/j. socscimed.2015.09.024.
38. Aitken Z, Simpson JA, Gurrin L, Bentley R, Kavanagh AM. Do material, psychosocial and behavioural factors mediate the relationship between disability acquisition and mental health? A sequential causal mediation analysis. Int J Epidemiol 2018 Jan;47(3):829-40. https://doi.org/10.1093/ ije/dyx277.
39. Kyaw-Myint SM, Strazdins L, Clements M, Butterworth P, Gallagher L. A method of identifying health-based benchmarks for psychosocial risks at work: A tool for risk assessment. Saf Sci 2017;93:143-51. https://doi. org/10.1016/j.ssci.2016.11.016.

DETAILS

Subject:	Employee benefits; Population; Disabilities; Sensitivity analysis; Workers; Confidence intervals; Gender; Disability; Households; Workers with disabilities; Costs; Sick leave; Employers; Employment interviews
Business indexing term:	Subject: Workers with disabilities Costs Sick leave Employers Employment interviews

Location:	Australia
Company / organization:	Name: Organization for Economic Cooperation &Development; NAICS: 541720
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm
Volume:	46
Issue:	3
Pages:	302-310,302A
Publication year:	2020
Publication date:	2020
Section:	Original article
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Journal Article
DOI:	https://doi.org/10.5271/sjweh.3865
ProQuest document ID:	2406984932
Document URL:	https://www.proquest.com/scholarly-journals/do-gender-psychosocial-job-stressors-modify/docview/2406984932/se-2?accountid=2111 60
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2023-07-03
Database:	Public Health Database

The COVID-19 (Coronavirus) pandemic: consequences for occupational health

Burdorf, A [1] ; Porru, F; Rugulies, R [1] Department of Public Health, Erasmus Medical Center, Rotterdam, The Netherlands

ABSTRACT (ENGLISH)

We live in unprecedented modern times experiencing how an outbreak of a particular viral disease, COVID-19, caused by SARS-CoV-2, also commonly referred to as the Coronavirus, is disrupting societies and personal lives. The virus is likely to spread to most, if not all, countries, illustrating the interconnectedness of the world. While many national measures to contain, suppress, mitigate, or delay the spread of the virus are being taken, there is great uncertainty as to which measures are appropriate or not, varying from instructions of stringent hand hygiene; travel restrictions; social distancing; and closure of schools, restaurants, bars and shops to a complete lock down of large parts of society. Here, Burdorf et al discuss the long-lasting societal effects of this pandemic.

FULL TEXT

Headnote

Key terms: Coronavirus; COVID-19; editorial; occupational health; occupational health; pandemic

We live in unprecedented modern times experiencing how an outbreak of a particular viral disease, COVID-19, caused by SARS-CoV-2, also commonly referred to as the Coronavirus, is disrupting societies and personal lives. The virus is likely to spread to most, if not all, countries, illustrating the interconnectedness of the world. At the time of writing, Italy and Spain have become the epicenters in terms of fatalities in Europe, whereas the United States has recorded the most diagnosed cases worldwide. While many national measures to contain, suppress, mitigate, or delay the spread of the virus are being taken, there is great uncertainty as to which measures are appropriate or not, varying from instructions of stringent hand hygiene; travel restrictions; social distancing; and closure of schools, restaurants, bars and shops to a complete lock down of large parts of society. Science-based evidence informing the policy about the efficaciousness and possible adverse effects of these measures are urgently needed. As there is a lack of both data and insight into the mechanisms of the pandemic, generating this science-based evidence will take some time. Key epidemiological numbers, such as the attack rate of the disease and the infection-hospitalization and infection-fatality ratios, are not yet available, and estimates based on the existing limited data come with huge uncertainties (1,2). Thus, scientists blindfolded by the lack of data have to inform a policy that needs to decide about far-reaching measures fundamentally changing societies and individuals' lives. It's an uncomfortable situation.

COVID-19 is a tremendous challenge for occupational health. Workers in many occupations are facing high risks of becoming infected. There is a long list of jobs that involve direct contact with the public and close physical proximity to others. Workers in shops, bars, restaurants, fast food, and delivery services are at increased risk for exposure to infected persons due to the large number of daily contacts. Barbers, manicurists, and physical therapists work in close proximity to their customers. However, there are also many jobs where workers have the freedom of being able to work from home, thus considerably reducing the risk to contract the virus. For example, the authors of this editorial are working from home, but communication is easy through email and Skype.

Without any doubt, healthcare personnel deservedly receive nationwide attention these days. They are at the forefront of combatting this outbreak. Not only is their work stress at record high, their healthcare organizations are under severe pressure and many are struggling to cope with care needs of so many critically ill patients simultaneously. Healthcare professionals are at increased risk of exposure to high viral load because of their close contact with COVID-19 patients, which puts them at risk of becoming infected. At the same time, they themselves are an important source of transmitting the disease to colleagues, patients, friends, and family. Healthcare workers cannot stay at home in times of capacity problems in health emergencies. In a recent letter, a physician asked himself the question: "Am I part of the cure, or am I part of the disease?" (3)

Early evidence from Wuhan, the origin of the worldwide outbreak, indicated that - of all Coronavirus infected cases - almost 4% had comprised healthcare personnel, and five deaths among healthcare workers had been confirmed (4). In Italy, the most affected country in Europe, on March 26, 2020, it was reported that more than 5,000 healthcare workers had tested positive for the Coronavirus and more than 40 had died as a result of COVID-19 (5). The daily reality in Italian hospitals is grim: insufficient testing capacity, lack of suitable protective equipment, lack of mechanical ventilators, wards not isolated from each other, and patients in beds in corridors. The capacity of the national health system is stretched to its limits and, in the most affected region of Lombardy, clearly insufficient (6). In such a crisis, it is imperative to ensure that healthcare workers are protected, for their own safety and to safeguard the healthcare system but also to prevent transmission of the virus. It is obvious that we have to revert to the proven strategies to protect workers by creating awareness of risks and providing personal protective equipment as well as appropriate hygiene procedures. Almost 15 years ago, prompted by the SARS epidemic, Descatha and colleagues (7) already pleaded for such contingency plans in healthcare in the event of an influenza pandemic.

Companies will have to deal with the psychosocial and psychological consequences of the current Coronavirus outbreak. Specifically, healthcare organizations will need to deal with insomnia, burnout, depressive symptoms, and post-traumatic stress disorders among healthcare workers. In Wuhan hospitals support teams have been set up to provide individual psychological guidance and group-based interventions (8). An important source of psychological distress are the impossible decisions (who to treat first?) under extreme work pressure. A recent analysis of previous major incidents called not only for peer-support programs during the crisis but also for active monitoring and adequate availability of mental treatment to prevent long-term damage to healthcare staff (9).

The long-lasting societal effects of this pandemic are impossible to estimate yet. National, regional or global economic recessions seem to be inevitable. We know from previous economic crises, such as the recession in Finland in the 1990s (10) and the global financial crisis of 2007-2009 (11,12) that there were marked effects on people's health, both on those who lost their jobs and those remaining at work. Thus, efforts on containment, suppression and mitigation are not only needed with regard to the virus but also with regard to possible adverse societal and economic consequences.

COVID-19 will have both a short-term and long-lasting impact on societies, healthcare systems, workplaces and individuals alike. As occupational health professionals we must contribute with our knowledge and insights to provide appropriate occupational health for all workers affected directly and indirectly by this pandemic.

Sidebar

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/32356896

Alex Burdorf and Fabio Porru

Department of Public Health

Erasmus Medical Center Rotterdam

Rotterdam, The Netherlands

[Email: a.burdorf@erasmusmc.nl]

Reiner Rugulies

National Research Centre for the Working Environment (NFA)

Department of Public Health and Department of Psychology,

University of Copenhagen

Copenhagen, Denmark

[email: rer@nfa.dk]

References

References

1. Ioannidis JPA. A fiasco in the making? As the coronavirus pandemic takes hold, we are making decisions without reliable data. STAT; 2020, March 17. https://www.statnews.com/2020/03/17/a-fiasco-in-the-making-as-the-coronavirus-pandemic-takes-hold-we-aremaking-decisions-without-reliable-data/
2. Lipsitch M. We know enough now to act decisively against Covid-19. Social distancing is a good place to start. STAT; 2020, March 18. https://www.statnews.com/2020/03/18/we-know-enough-now-to-act-decisively-against-covid-19/
3. Rose C. Am I part of the cure or I am part of the disease. N Engl J Med 2020, March 18 (Epub ahead of print). https://doi.org/10.1056/ NEJMp2004768
4. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020, February 24 (Epub ahead of print). https://doi.org/10.1001/jama.2020.2648
5. Giuffrida A, Tondo L. 'As if a storm hit': more than 40 Italian health workers have died since crisis began. The Guardian. 26 March 2020. https://www.theguardian.com/world/2020/mar/26/as-if-a-storm-hit-33-italian-health-workers-have-died-since-crisis-began.
6. Remuzzi A, Remuzzi G. Covid-19 and Italy: what next? Lancet 2020, March 12 (Epub ahead of print). https://doi.org/10.1016/501406736(20)30627-9.
7. Descatha A, Dolveck F, Salomon J. A contingency plan for health care worker protection in the event of a flu pandemic. J Occup Environ Med 2006;48:660-1. https://doi.org/10.1097/01.jom.0000226919.79483.b7
8. Kang L, Li Y, Hu S, Chen M, Yang C, Yang BX et al. The mental health of medical workers in Wuhan, China dealing with the 2019 novel coronavirus. Lancet Psychiatry 2020;7:e13-e14. https://doi.org/10.1016/S2215-0366(20)30047-X
9. Greenberg N, Docherty M, Gnanapragasam S, Wessely S. Managing mental health challenges faced by healthcare workers during covid-19 pandemic. BMJ 2020;368:m1211. https://doi.org/10.1136/bmj.m1211
10. Vahtera J, Kivimäki M, Pentti J. Effect of organisational downsizing on health of employees. Lancet 1997;350(9085):1124-8. https:// doi.org/10.1016/S0140-6736(97)03216-9
11. Karanikolos M, Heino P, McKee M, Stuckler D, Legido-Quigley H. Effects of the global financial crisis on health in high-income OECD countries: A narrative review. Int J Health Serv 2016;46:208-40. https://doi.org/10.1177/0020731416637160
12. Torá I, Martínez JM, Benavides FG, Leveque K, Ronda E. Effect of economic recession on psychosocial working conditions by workers' nationality. Int J Occup Environ Health 2015;21:328-32. https://doi.org/10.1080/10773525.2015.1122369

DETAILS

Subject:	Pandemics; Social distancing; Severe acute respiratory syndrome coronavirus 2; Hygiene; Disease control; Medical personnel; Viruses; Viral diseases; COVID-19; Schools; Coronaviruses; Fatalities; Decision making; Epidemics; Occupational health; Public health; Mental health; Disease transmission; Economic crisis; Employment; Personal hygiene; Workers; Recessions
Business indexing term:	Subject: Economic crisis Occupational health Employment Workers Recessions
Location:	Italy; Europe; China
Publication title:	Scandinavian Journal of Work, Environment &Health; Stockholm

Volume:	46
Issue:	3
Pages:	229-230,229A
Publication year:	2020
Publication date:	2020
Section:	Editorial
Publisher:	Scandinavian Journal of Work, Environment &Health
Place of publication:	Stockholm
Country of publication:	Finland, Stockholm
Publication subject:	Occupational Health And Safety
ISSN:	03553140
e-ISSN:	1795990X
Source type:	Scholarly Journal
Language of publication:	English
Document type:	Editorial
DOI:	https://doi.org/10.5271/sjweh.3893
ProQuest document ID:	2406984882
Document URL:	https://www.proquest.com/scholarly-journals/covid-19-coronavirus-pandemic-consequences/docview/2406984882/se-2?accountid=211160
Copyright:	Copyright Scandinavian Journal of Work, Environment &Health 2020
Last updated:	2023-02-28
Database:	Public Health Database

Bibliography

Citation style: APA 6th - Annotated with Abstracts - American Psychological Association, 6th Edition

Nikkilä, A., Arvela, H., Mehtonen, J., Raitanen, J., Heinäniemi, M., Lohi, O., & Auvinen, A. (2020). Predicting residential radon concentrations in finland: Model development, validation, and application to childhood leukemia. Scandinavian Journal of Work, Environment & Health, 46(3), 278-292,278A. doi:https://doi.org/10.5271/sjweh.3867

Objectives Inhaled radon gas is a known alpha-emitting carcinogen linked especially to lung cancer. Studies on higher concentrations of indoor radon and childhood leukemia have conflicting but largely negative results. In this study, we aimed to create a sophisticated statistical model to predict indoor radon concentrations and apply it to a Finnish childhood leukemia case-control dataset.Methods Prediction was based on ~80 000 indoor radon measurements, which were linked to national registries for potential indoor radon predictors based on the literature. In modelling, we used classical methods, random forests and deep neural networks. We had 1093 cases and 3279 controls from a nationwide case-control study. We estimated odds ratio (OR) for childhood leukemia using conditional logistic regression adjusted for potential confounders.Results The r2 of the final log-linear model was 0.21 for houses and 0.20 for apartments. Using random forest method, we were able to obtain slightly better fit for both houses (r2 = 0.28) and apartments (r2 = 0.23). In a risk analysis based on the case-control data with log-linear model, we observed a non-significant (P=0.54) increase with predicted radon concentrations OR for the 2nd quartile 1.08, 95% confidence interval (CI) 0.77-1.50, OR 1.10 with 95% CI 0.79-1.53 for the 3rd, and 1.29 with 95% CI 0.93-1.77 for the highest quartile].Conclusions Our modelling and the previously published models performed similarly but involves major uncertainties, and the results should be interpreted with caution. We observed a slight non-significant increase in risk of childhood leukemia related to higher average indoor radon concentrations.

Nielsen, M. B., & Knardahl, S. (2020). The impact of office design on medically certified sickness absence. Scandinavian Journal of Work, Environment & Health, 46(3), 330-334,330A. doi:https://doi.org/10.5271/sjweh.3859

Objective The aim of this study was to determine the impact of three different office designs (cellular office, shared office, and open-plan workspace) on the risk of medically certified sickness absence and the number of days, respectively, of medically certified sickness absence over a 12-month follow-up period. Methods The study relied on a combination of self-report survey questionnaire data on office design supplemented with official registry data number of days with sickness absence from the Norwegian Labor and Welfare Administration. The sample comprised 6328 Norwegian office workers (57% women, age range: 19-70 years, mean age: 44 years). Results Adjusting for survey year, employees working in a shared office risk ratios (RR) 1.18, 95% confidence interval (CI) 1.10-1.27] and an open-plan workspace (RR 1.12, 95% CI 1.02-1.22) had significantly higher risk of having had medically instances of certified sickness absence when compared to employees working in a cellular-office. Office design was not related to the number of days with absence. The associations were consistent across organizational affiliation, age, gender, whether the respondent had leadership responsibility, and educational level. Conclusion The use of shared offices and open-plan workspaces is a risk factor for medically certified sickness absence. Providing employees with the opportunity to work in cellular offices may reduce absence rates. Key terms cellular office; health; open office; open-plan office; registry data; shared office; shared workstation; sick leave; workability.

Yung, M., Evanoff, B. A., Buckner-Petty, S., Roquelaure, Y., Descatha, A., & Dale, A. M. (2020). Applying two general population job exposure matrices to predict incident carpal tunnel syndrome: A cross-national approach to improve estimation of workplace physical exposures. Scandinavian Journal of Work, Environment & Health, 46(3), 248-258,248A. doi:https://doi.org/10.5271/sjweh.3855

Objectives A job exposure matrix (JEM) is a tool to estimate workers' exposure to occupational physical risk factors. We evaluated the performance of two general population JEM (CONSTANCES and O·NET) to detect known exposure-disease relationships in an American prospective cohort study. We compared exposure estimates from three data sources and explored whether combining exposures from these two JEM, or combining exposure from each JEM with individual-level measures, improved prediction of carpal tunnel syndrome (CTS).Methods Using Cox proportional hazard models, we evaluated relationships between physical work exposure and incident CTS of 2393 workers using JEM-assigned and individual-level measure exposure information. We compared exposure estimates using Spearman's rank correlation and Cohen's kappa. We compared combined exposure models to single source exposure models by using binomial logistic regression and examined differences based on model fit and performance.Results The O·NET JEM hazard ratio (HR) range 1.3-2.01] demonstrated generally similar exposure-disease associations as individual-level measures (HR range 1.00-1.42); we found fewer associations with the CONSTANCES JEM (HR range 1.08-2.05). Comparisons between the three sources showed stronger correlations and agreement at the job versus worker level. Combined models improved goodness-of-fit and had lower Akaiké information criterion (AIC) values compared to single-source models.Conclusions JEM can be applied cross nationally and there is potential to combine complementary exposure methods to improve estimation of workplace physical exposures in the prediction of CTS. More investigations are needed to explore exposure-disease associations in other samples and combinations of exposure data from different methods.

Kreshpaj, B., Orellana, C., Burström, B., Davis, L., Hemmingsson, T., Johansson, G., . . . Bodin, T. (2020). What is precarious employment? A systematic review of definitions and operationalizations from quantitative and qualitative studies. Scandinavian Journal of Work, Environment & Health, 46(3), 235-247,235A. doi:https://doi.org/10.5271/sjweh.3875

Objectives The lack of a common definition for precarious employment (PE) severely hampers the comparison of studies within and between countries, consequently reducing the applicability of research findings. We carried out a systematic review to summarize how PE has been conceptualized and implemented in research and identify the construct's dimensions in order to facilitate guidance on its operationalization.Methods According to PRISMA guidelines, we searched Web of Science and Scopus for publications with variations of PE in the title or abstract. The search returned 1225 unique entries, which were screened for eligibility. Exclusion criteria were (i) language other than English, (ii) lack of a definition for PE, and (iii) non-original research. A total of 63 full-text articles were included and qualitative thematic-analysis was performed in order to identify dimensions of PE.Results We identified several theory-based definitions of PE developed by previous researchers. Most definitions and operationalizations were either an accommodation to available data or the direct result of qualitative studies identifying themes of PE. The thematic-analysis of the selected articles resulted in a multidimensional construct including the following three dimensions: employment insecurity, income inadequacy, and lack of rights and protection.Conclusions Despite a growing number of studies on PE, most fail to clearly define the concept, severely restricting the advancement of the research of PE as a social determinant of health. Our combined theoretical and empirical review suggests that a common multidimensional definition could be developed and deployed in different labor market contexts using a variety of methodological approaches.

Too, L. S., Leach, L., & Butterworth, P. (2020). Is the association between poor job control and common mental disorder explained by general perceptions of control? findings from an australian longitudinal cohort. Scandinavian Journal of Work, Environment & Health, 46(3), 311-320,311A. doi:https://doi.org/10.5271/sjweh.3869

Objectives This study sought to examine the influence of general perceptions of control on the association between job control and mental health. Methods We used four waves of data from a cohort of mid-aged adults from the Personality and Total Health (PATH) Through Life Study (baseline N=2106). Key measures included job control and likelihood of experiencing a common mental disorder (anxiety and/or depression). The data were analyzed using longitudinal randomintercept regression models, controlling for a range of potential confounders including general perceptions of control (ie, not isolated to the work context) via a measure of mastery. The analyses isolated the effect of withinperson changes in job control on mental health (apart from between-person differences). Results The results show that the effect of job control remained significant after adjusting for general perceptions of control and other confounders. The within-person effect in the model demonstrated that, when workers had low job control, they were twice as likely to experience a common mental disorder odds ratio (OR) 2.04, 95% confidence interval (CI) 1.53-2.73]. Conclusions Individuals' general perceptions of control in life does not account for the association between low job control and poor mental health. The findings add a new layer of evidence to the literature demonstrating that lack of autonomy at work is an independent predictor of employees' mental health. Increasing employee control should be integrated into workplace strategies to promote mental health. Key terms Australia; depression; job stressor; mental health; psychosocial; stress.

Peters, S. (2020). Although a valuable method in occupational epidemiology, job-exposure matrices are no magic fix. Scandinavian Journal of Work, Environment & Health, 46(3), 231-234,231A. doi:https://doi.org/10.5271/sjweh.3894

Peters discusses the job-exposure matrices (JEM). JEM are a common method for exposure assessment in occupational epidemiology. A recent review on methods for retrospective exposure assessment in the general population revealed that more than a quarter of the studies on cancer applied a JEM. Where JEM originally assigned exposures at a qualitative or semi-quantitative level based on expert ratings, quantitative exposure estimates can also be derived when measurements are used to calibrate these ratings. A JEM typically consists of job and exposure axes. The major advantage of JEM is that job histories can be translated into specific exposures in a systematic and unbiased way. It is basically a computerized linkage of exposure estimates to job codes, and, as such, JEM represent a highly efficient and reproducible methodology. This way, a standardized exposure assessment within and between studies can be guaranteed, and any misclassification is expected to be non-differential with respect to the health outcome. Once developed, a JEM is relatively easy to apply and less costly than case-by-case expert assessment.