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Scientific challenges of studying shift schedule design

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ABSTRACT (ENGLISH)

The study of shift schedule design, and its impact on the health, safety and the performance of shiftworkers, has seen considerable advances in methodology in the last decade. Much of the early research that helped identify shift schedule design principals was based on observational studies. Quite many featured cross-sectional designs that were subject to residual confounding from unadjusted potential confounders. Moreover, the early studies were almost universally based on self-reported exposure and many relied upon self-reported outcomes, making them subject to information bias. Researchers have since built on the findings of earlier research with more sophisticated and robust designs and metrics, many of which are exemplified in studies that have been published in this journal. These provide a firmer evidence base on which to develop recommendations for the design of shift schedules. Here, several methodological approaches in the study of shift schedule design are discussed.

FULL TEXT

The study of shift schedule design, and its impact on the health, safety and the performance of shiftworkers, has seen considerable advances in methodology in the last decade. Much of the early research that helped identify shift schedule design principals was based on observational studies. Quite many featured cross-sectional designs that were subject to residual confounding from unadjusted potential confounders (eg, socioeconomic status, health-driven selection bias). Moreover, the early studies were almost universally based on self-reported exposure and many relied upon self-reported outcomes, making them subject to information bias (1).

Researchers have since built on the findings of earlier research with more sophisticated and robust designs and metrics, many of which are exemplified in studies that have been published in this journal. These provide a firmer evidence base on which to develop recommendations for the design of shift schedules. The fundamental aim of research is to optimise the balance between precision (internal validity), achieved through having control over variables and the study setting; existential realism, achieved through the collection of data in realistic situations; and generalisability of results, from the study sample to the target population (2). In their attempts to achieve this optimal balance, shiftwork researchers have adopted various methodological approaches that try to combine the existential realism (and, in some cases, the generalisability) of the field study with the precision of the laboratory simulation.

The randomised control trial (RCT) is widely regarded as the gold standard of methodological design because confounders are balanced across comparison groups, giving statistical independence between the confounders and the treatment assignment. However, true randomisation to a treatment condition can be impractical, expensive or unethical in field studies that are conducted in the workplace. Hence, true RCT with randomisation at participant level are rare in comparisons of working time arrangements. One of the very few of these types of studies examined the impact of compressed work weeks among police officers who were randomly allocated to either 8-, 10- or 12-hour shifts (3). The results were favourable towards compressing the working week from 8- to 10-hour shifts but somewhat less favourable towards 12-hour shifts.

When the fully experimental approach is not feasible in field settings, another approach to controlling confounders is to use participants as their own control. This approach was adopted in a 'quasi-experimental' study (also of police officers), examining the impact of night shift intensity on sleep (4). Each participant undertook three conditions: (i) 2 nights followed by 2 rest days; (ii) 4 nights + 4 rests; and (iii) 7 nights + 7 rests. The order of conditions was allocated individually on a non-random basis that was determined according to the convenience of the rota planner. It was found that sleep was impaired on night shifts and did not improve with an increasing number of consecutive nights, leading to an accumulation of sleep debt with more consecutive nights.

Another form of quasi-experimental study is the group intervention study, where researchers follow the implementation of a change in predictor (eg, working time arrangements) among one group of workers and compare them with a no-change group (a 'difference-in-difference' design). Such changes often take place at the instigation of, or are largely guided by, the managers of the organisation in which the study takes place. Thus, potential biases may creep in, such as the way in which groups of participants (eg, departments within the organisation) are allocated to conditions. Moreover, the success of an intervention is likely to be influenced by the process of implementation (eg, the way in which the change is introduced and communicated to the workforce, and the actions of the organisation's management during implementation). Successful high-quality intervention studies are relatively rare in the study of shift schedule design. Nevertheless, the approach remains a potentially fruitful one, especially in light of the recent publication of a framework for the development of high-quality interventions (5). While the framework's authors acknowledge the importance of obtaining unbiased estimates (ie, adequately controlling for confounders), they also emphasise the need to understand how an intervention contributes to change and the ways in which it interacts with wider dynamic systems within the operational setting.

While intervention studies conducted at the group level remain relatively rare in the study of shift schedule design, recent years have seen an increasing number of observational studies examining the impact of changes in working time arrangements at the individual level. One of the more robust forms of this approach is the nonrandomised pseudo trial, in which data from observational studies are analysed in a way that mimics an RCT design (6). This approach was exemplified in a study of night work and the risk of developing common mental disorders (CMD; 7). From baseline, participants were followed up on two occasions, four years apart. At the first follow up, participants were divided into those who had changed schedule since baseline (eg, from non-night to night work) and those who had not, while excluding participants who experienced a change in CMD status in that same initial four-year period (eg, if they had developed a CMD since baseline). At the second follow up, the two groups were compared with respect to their change in CMD status between the first and second follow up. Analyses were also included which adjusted for selection bias, namely the tendency for night workers who develop CMD to transfer to daywork. This bias is a form of the 'healthy worker effect' (8), which has long been identified as an obstacle to establishing causal relationships between shift schedule and disease outcomes, and continues to be a challenge to this day.

Case-crossover designs have been employed in several recent studies of shift schedule design. This is essentially a within-participant variation of the case-control study. It involves comparing the relative likelihoods of two scenarios: an outcome event of interest (eg, injury, disease onset or behavioural change) being preceded by the predictor of interest (eg, working a night shift), and the same outcome occurring during a comparable time window when the predictor was not present. The design is most appropriately employed when exposure is intermittent, the effect on risk is immediate and transient, and the outcome is abrupt. Thus, for example, casecrossover designs have been used to study the impact of shift schedule characteristics (eg, shift length, time of day, on-call shifts, shift intensity and weekly work hours) on outcomes such as occupational injuries and on short term sickness absence (9-14). However, the approach has the potential to be applied more widely, eg, to study single changes in exposure level, gradual effects on risk and outcomes with insidious onsets (15).

Turning from study design to measurement, one of the most significant developments in the study of working time arrangements in recent years has been the use of register-based working time data to assess exposure (eg, payroll-based registry data of planned and/or executed work hours; 16). The advantage of this approach over traditional self-reported work hours data is that it reduces the risk of information bias due to poor exposure assessment, thereby reducing the risk of exposure misclassification and consequent false negative results. Such precise and accurate exposure assessment is crucial for the identification of etiological relationships, especially when effect sizes are small. Moreover, register-based working time data can provide a fine-grained assessment of exposure over time, which is becoming increasingly important with the trend towards more diverse, flexible and irregular work hours. Some disadvantages of register-based work hours data are that, unlike self-report data, they often only provide exposure assessment over a relatively short historical period (eg, they offer no possibility to assess life-time exposure), and that they only assess exposure within the main job and paid hours (ie, there is usually no assessment relating to second jobs or unpaid work). Moreover, analysing register-based work hours data presents additional challenges for the researcher, compared to traditional data sources. These challenges relate to the processing and cleaning of raw pay-roll data, its transformation into accurate and meaningful schedule parameters, and the substantial computing-power requirements of analysing such very large datasets (M. Härmä - personal communication).

Researchers have also recently drawn upon register data for the assessment of outcomes in relation to working time arrangements. Such studies are most common in the Scandinavian countries where national populationwide register data is collected relating to, for example, the purchase of prescribed medication, hospital treatment, and occupational accidents. Again, register-based assessment eliminates some of the problems commonly associated with self-report (eg, reporting bias and inaccuracy), but it also has potential disadvantages. One potential weakness is that register data is reliant on accurate identification processes eg, accurate diagnosis and consistent treatment decisions by physicians or accurate reporting of accidents at work. This could be especially problematic if the diagnosis- / reporting-behaviour is related to exposure. For example, a physicians' decisions on diagnosis and treatment may be affected by their patients' status as a shiftworker or accident reporting procedures at a workplace may differ between day and night time. Some recent studies of working time arrangements have combined register-based assessment of both exposure and outcome, to the exclusion of any self-report measures (eg, 17, 18). While this approach eliminates reporting bias and inaccuracy, the absence of self-report data limits the possibilities for adjusting for potential confounders.

The foregoing only scratches the surface of the diverse range of methodical approaches and measurement techniques available to shift work researchers. Other innovative methods applied to the study of shift schedule characteristics include deriving exposure through job exposure metrics (eg, 19) and through data mining techniques (20), and using co-twin designs to evaluate familial confounding in the impact of nightwork (eg, 21). In addition, increasingly sophisticated wearable technology is available for the intensive measurement of sleep and physiological functioning in field studies (22). Other tools are emerging that may yet prove useful in the study of working time arrangements. For example, today's researchers studying shift schedule design still often have to rely on observational data and so have much to gain from techniques that strengthen causal inferences made from observational data (23).

While the employer traditionally largely determines shift schedules, there is an increasing trend in some quarters to give shiftworkers a greater voice in their working time arrangements (eg, 24). Irrespective of who is designing the schedules, optimising the design requires balancing factors including productivity, operational logistics, safety, work-life balance and worker health. Science plays an important role in guiding those who are seeking to achieve this balance. The more reliable and accurate the science, the greater its contribution to promoting the health and safety of shiftworkers and the public they serve.

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Healthcare workers' SARS-CoV-2 infection rates during the second wave of the pandemic: follow-up study

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ABSTRACT (ENGLISH)

Objectives This study aimed to assess if, during the second wave of the COVID-19 pandemic, healthcare workers had increased severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection rates, following close contact with patients, co-workers and persons outside work with COVID-19. Methods A follow-up study of 5985 healthcare workers from Denmark was conducted between November 2020 and April 2021 and provided day-to-day information on COVID-19 contacts. SARS-CoV-2 infection was defined by the first positive polymerase chain reaction (PCR) test ever. Data was analyzed in multivariable Poisson regression models. Results The SARS-CoV-2 infection rates following close contact 3-7 days earlier with patients, co-workers and persons outside work with COVID-19 were 153.7, 240.8, and 728.1 per 100 000 person-days, respectively. This corresponded with age, sex, month, number of PCR tests and mutually adjusted incidence rate ratios of 3.17 [40 cases, 95% confidence interval (CI) 2.15-4.66], 2.54 (10 cases, 95% CI 1.30-4.96) and 17.79 (35 cases, 95% CI 12.05-26.28). The risk of SARS-

CoV-2 infection was thus lower, but the absolute numbers affected was higher following COVID-19 contact at work than COVID-19 contact off work. Conclusions Despite strong focus on preventive measures during the second wave of the pandemic, healthcare workers were still at increased risk of SARS-CoV-2 infection when in close contact with patients or co-workers with COVID-19. There is a need for increased focus on infection control measures in order to secure healthcare workers' health and reduce transmission into the community during ongoing and future waves of SARS-CoV-2 and other infections.

FULL TEXT

Headnote

Objectives This study aimed to assess if, during the second wave of the COVID-19 pandemic, healthcare workers had increased severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection rates, following close contact with patients, co-workers and persons outside work with COVID-19.
Methods A follow-up study of 5985 healthcare workers from Denmark was conducted between November 2020 and April 2021 and provided day-to-day information on COVID-19 contacts. SARS-CoV-2 infection was defined by the first positive polymerase chain reaction (PCR) test ever. Data was analyzed in multivariable Poisson regression models.
Results The SARS-CoV-2 infection rates following close contact 3-7 days earlier with patients, co-workers and persons outside work with COVID-19 were 153.7, 240.8, and 728.1 per 100 000 person-days, respectively. This corresponded with age, sex, month, number of PCR tests and mutually adjusted incidence rate ratios of 3.17 [40 cases, 95% confidence interval (CI) 2.15-4.66], 2.54 (10 cases, 95% CI 1.30-4.96) and 17.79 (35 cases, 95% CI 12.05-26.28). The risk of SARS-CoV-2 infection was thus lower, but the absolute numbers affected was higher following COVID-19 contact at work than COVID-19 contact off work.
Conclusions Despite strong focus on preventive measures during the second wave of the pandemic, healthcare workers were still at increased risk of SARS-CoV-2 infection when in close contact with patients or co-workers with COVID-19. There is a need for increased focus on infection control measures in order to secure healthcare workers' health and reduce transmission into the community during ongoing and future waves of SARS-CoV-2 and other infections.
Key terms coronavirus; COVID-19; epidemiology; infectious disease; longitudinal study; loss of taste and smell; occupational safety; PCR; polymerase chain reaction; risk factor.

The first wave of the SARS-CoV-2 pandemic was globally characterized by widespread lack of personal protective equipment (PPE), confusing PPE guidelines and lack of SARS-CoV-2 testing and contact tracing (1). Healthcare workers were at highly increased risk and mortality of COVID-19 (2-6). From January to October 2020, healthcare workers from four UK teaching hospitals exposed to patients and healthcare workers infected with SARS-CoV-2 had infection rates of 0.8 and 0.6 per 1000 person-days at risk, respectively, well above the background rate of 0.1 per 1000 person-days at risk (7). From March to April 2020, front-line healthcare workers in the UK and USA reporting adequate PPE use when in direct contact with COVID-19 patients showed a fivefold increased self-reported positive polymerase chain reaction (PCR) testing rate for SARS-CoV-2 of 553 per 100 000 (2). Increased SARS-CoV-2 seropositivity was reported among healthcare workers in close contact with patients (8-11), co-workers (8, 9), household members and other persons outside work with COVID-19 (8, 9, 12-15), but not consistently (13-16).

A considerable increase in preventive measures was initiated in multiple countries including Denmark (13), and it was expected that the pandemic afflicting so many healthcare workers was brought under control during the second wave. Our main objective was to study if, during the second wave of the COVID-19 pandemic, healthcare workers had increased SARS-CoV-2 infection rates following close contact with patients, co-workers and persons outside work with COVID-19.

Methods

Study design and population

This is a dynamic follow-up study with day-to-day selfreported information on COVID-19 contacts. Outcome is incident SARS-CoV-2 infection. Person-day at risk is the unit of analysis. The study population comprised healthcare workers at hospitals and related technical, administrative and other staff of the Central Denmark Region (hereafter referred to as healthcare workers).

General surveillance and infection control recommendations

PCR testing for SARS-CoV-2 was freely accessible at no cost for all Danish citizens independent of symptoms. All hospital workers with any patient contact were urged to be PCR tested bi-weekly until 26 January 2021, thereafter weekly. PCR test results were provided on average 24-36 hours after sample collection. SARS-CoV-2 infection rates in the second wave of the pandemic peaked in Denmark on 16 December 2020, with 4387 PCR-verified cases in a population of 5 771 877 citizens.

All healthcare workers were instructed to follow general guidelines for infection control and wear surgical masks in all indoor areas with public or patient access and maintain physical distance to other persons whenever possible. All workers with non-critical functions were sent home on 11 December 2021, and for the remaining study period.

During care for patients diagnosed with or under suspicion of COVID-19, all staff were instructed to wear a fluid-repellent disposable gown with long sleeves, disposable medical gloves, surgical mask and protective glasses or visor. Moreover, during procedures with risk of aerosol generation (eg, high flow oxygen therapy) the surgical mask should be replaced by a filtering face piece 2 or 3 (FFP2, FFP3) respirator. The healthcare workers were instructed how to do a positive pressure seal check of the respirators, but no formal fit test was done as recommended by Center for Disease Control (18). There was sufficient supply of PPE during the study period.

Following close contact with persons diagnosed with COVID-19 without prescribed PPE for >15 minutes, individuals were required to go into self-isolation and be PCR tested at day four and six. Self-isolation could be cancelled following two negative tests or, in case of a positive test, 48 hours after symptom cessation or seven days after the positive test if asymptomatic. Detailed infection control for COVID-19 for employees of the Central Denmark Region during the COVID-19 pandemic can be found in the supplementary material (www.sjweh.fi/article/4049).

Exposure assessment of COVID-19 contacts

Each day during follow-up at 15:30 hours, study participants received a text message linking to a questionnaire. They were asked to report any incident of close contact within a one-meter distance with patients and persons outside work with COVID-19 during the current and the previous 1-2 and 3-4 days. Participants were also asked to report incidents of close contact with co-workers with COVID-19 during the previous 1-2 and 3-4 days, but not the current day, because co-workers with known COVID-19 would not be present at work.

We classified each day of follow-up as exposed to contact with COVID-19 patients if participants reported such contact at least once during the previous 3-7 days. Otherwise, each day of follow up was classified with no close contact with COVID-19 patients if participants reported this for >3 days during the previous 3-7 days. Days of follow-up not fulfilling these two criteria were classified with unknown close contact with COVID-19 patients. A similar approach was used to assign exposure status following close contact with co-workers and persons outside work. Thus, each day of follow-up was classified as exposed (yes, no, unknown) to patients, coworkers and persons outside work with COVID-19. To account for the incubation period, we decided to focus on the 5-day exposure window 3-7 days earlier (19).

SARS-CoV-2 infection, vaccination and COVID-19 symptoms

The primary outcome measure was incident SARSCoV-2 infection defined as the first positive PCR test ever recorded in a regional register with complete coverage of all tests conducted in the population since 27 February 2020. A regional register also provided information about all COVID-19 vaccinations since 27 December 2020. As a secondary outcome measure, we included first report of loss of taste and smell as asked for in the daily questionnaire because this was a key symptom of COVID-19 during the early waves of the pandemic and should be unaffected by potential biases related to being PCR tested for SARS-CoV-2 (20).

Population characteristics

Information on age, sex, occupation and department of employment was obtained from the personnel records of the Central Denmark Region. At baseline, participants reported information on smoking, height and weight that allowed calculation of body mass index (BMI), airways disease (chronic obstructive pulmonary disease, asthma, rhinitis). Participants reported non-compliance with PPE guidelines in the daily questionnaire by responding to the following two questions: "Has there within the last 24 hours been situations where you did not use the recommended personal protective equipment? If yes, during which tasks did you not use the recommended personal protective equipment?".

Statistical analyses

Study participants were followed daily from seven days after the first daily questionnaire response - 25 November 2020 - at the earliest, until first positive test for SARS-CoV-2, seven days after full vaccination (21) or 30 April 2021. Each day of follow-up was classified according to close contact (yes, no, unknown) with patients, co-workers and persons outside work with COVID-19 according to the previously defined criteria. Participants may have experienced all contact forms several times during follow-up and thus move in and out of exposures.

Study population characteristics were described for the person-days at risk. Sex, age, occupation, department, smoking, BMI, and lung disease were reported at baseline and did not vary during follow up. PCR testing, on the other hand like close contact with patients, co-workers and persons outside work with COVID19, varied day-to-day, and we therefore reported PCR testing for three time windows: 1-2, 3-7 and >8 days earlier reflecting time after, during, and before the 5-day COVID-19 exposure window.

We used generalized linear models with log-link assuming a Poisson distribution with person-days as offset representing the time at risk to derive incidence rate ratios (IRR) with 95% confidence intervals (CI) for SARS-CoV-2 infection following close contact versus no close contact with patients, co-workers and persons outside work with COVID-19. Adjusted IRR were mutually adjusted for the other types of COVID-19 contact, sex, age (continuous) and month (6 categories, November 2020-April 2021) as decided a priori. We furthermore adjusted for number of PCR tests made before, during, and after the 5-day exposure window (>8, 3-7 and 1-2 days previously). However, this only affected IRR estimates marginally, and in the final models, we included the cumulative number of earlier PCR tests as a continuous variable. In the analyses, number of previous PCR tests and contact with patients, co-workers and persons outside work were treated as time-varying day-to-day.

We excluded person-days with missing information on close contact with patients, co-workers and persons outside work diagnosed with COVID-19. We abstained from imputing the missing values. This was because a high fraction of participants worked part time or irregular shifts with at least two days off work with no close contact with patients or co-workers at unpredictable days during a given week. Information on the covariates of the adjusted models were complete.

In a sub-analysis, we restricted the data to persondays at risk with close contact either with patients, co-workers or persons outside work with COVID-19, excluding person-days with combined close contacts. Based on this data, we estimated the IRR of SARSCoV-2 infection following close contact with either patients or co-workers using close contact with persons outside work as the reference.

Analyses of loss of taste and smell followed a similar setup as analyses of SARS-CoV-2 infection, but we did not censor subjects when testing PCR positive for SARS-CoV-2 and did not include number of earlier PCR tests in the adjusted models.

In sensitivity analyses of possible differential recall of close COVID-19 contacts, we excluded contact information obtained after a given day of follow-up (ie, based on questionnaire reports for the previous 1-2 and 3-4 days), when PCR test results were available for the participants. This excluded all information on close contact with co-workers with COVID-19 because this was only reported for the previous 1-2 and 3-4 days.

Results

A total of 26 089 healthcare workers were invited to the study on 17 November 2020. After excluding 724 who tested positive for SARS-CoV-2 before the start of follow-up, 25 365 healthcare workers (3 253 671 persondays) were candidates for inclusion and 6337 (753 607 person-days) participated (table 1). After excluding person-days with missing information on close contact with patients, co-workers or persons outside work with COVID-19, the study population included 5985 healthcare workers providing 514 165 person-days at risk. The daily testing rates were

5.5% for the invited population and 7.1% for the study population. Altogether, 448 748 daily questionnaire responses were collected from the study population during follow-up, corresponding with an 87.3% coverage. SARS-CoV-2 infection rates in the invited population and the study population were 28.6 and 30.9 per 100 000 person-days.
Table 2 presents characteristics (person-days) of the invited population and the study population by COVID-19 contacts 3-7 days earlier. The study population included 88.6% women and the mean age was 48.0 years compared with 83% women and a mean age of 43.6 years for the invited population. Compared to the invited healthcare workers, more study participants had been PCR tested earlier. Only minor occupation and department differences between the invited and the participating populations were seen, except for relatively more participants from departments with less frequent patient contact.
Participants who reported one type of close COVID-19 contact more often reported the other types of close COVID-19 contact. All types of COVID-19 contact were associated with more frequent PCR testing, especially during the previous 1-2 days. More nurses had close contact with patients and co-workers with COVID-19 than other occupations. Only small differences were seen for department, smoking status, BMI and lung diseases.
After having close contact with COVID-19 patients 3-7 days earlier, 40 participants tested positive for SARS-CoV-2, while 119 tested positive after no such known contact (table 3). This corresponded with infection rates of 153.7 and 24.4 per 100 000 person-days and an adjusted IRR of 3.17 (95% CI 2.15-4.66). After having close contact with co-workers and persons outside work with COVID-19 3-7 days earlier, 10 and 35 participants tested positive corresponding with infection rates of 240.8 and 728.1 per 100 000 person-days, respectively. The infection rates among those with no such known contacts were 29.2 and 24.3 per 100 000 person-days and the adjusted IRR were 2.54 (95% CI 1.30-4.96) and 17.79 (95% CI 12.05-26.28), respectively.
When comparing the risk of SARS-CoV-2 infection following close contact with either patients or co-workers with close contact with persons outside work with COVID-19, excluding person-days and cases with combined exposures, we observed IRR of 0.17 (34 cases, 95% CI 0.10-0.28) for patients and 0.21 (5 cases, 95% CI 0.08-0.54) for co-workers (table 4). This analysis included 34 cases in the reference group with COVID-19 contact outside work.
A total of 24 participants with incident loss of taste and smell had experienced close contact with COVID19 patients (table 5). This corresponded with an IRR of 41.4 per 100 000 person-days and an adjusted IRR of 1.48 (95% CI 0.95-2.29). Following close contact with co-workers and persons outside work with COVID-19, the adjusted IRR of loss of taste and smell were 2.56 (95% CI 1.24-5.30) and 10.82 (95% CI 7.33-15.98). Among those reporting loss of taste and smell, 36% had a positive PCR test earlier.
The infection rate in the study population declined from January to April 2021, increased by number of PCR tests 3-7 days earlier and were higher for departments of medicine and among nurses compared with other departments and occupations. No clear infection rate patterns were seen for the other population characteristics (supplementary table S1).
Participants reported an overall 2% non-compliance with PPE guidelines during 187 413 daily procedures. For respiratory procedures with potential for higher exposure levels, this percentage was 4.8% (supplementary table S2).
Sensitivity analyses that only included COVID-19 contact information obtained before results of the PCR tests were available, showed an infection rate of 155.2 per 100 000 person-days and an adjusted IRR of 3.52 (95% 2.41-5.13) following close contact with COVID19 patients (supplementary table S3). The IRR following close contact with persons outside work with COVID-19 was 14.19 (95% CI 8.27-24.33). No results were available for close contact with co-workers with COVID-19 because this information was obtained after PCR test results were available for those tested.

Discussion

Principal findings

This follow-up study of healthcare workers was conducted from 25 November 2020 to 30 April 2021 during the second wave of the pandemic in Denmark. The SARS-CoV-2 infection rates following close contact with patients, co-workers, and persons outside work with COVID-19 were, respectively, 153.7, 240.8 and 728.1 per 100 000 person-days. This corresponded to about 3, 2.5 and 18-fold increased adjusted IRR when compared with no such contacts representing the background risk. When compared with close contacts outside work, the adjusted IRR of close contacts with patients and co-workers with COVID-19 were about 5-fold decreased. Among all healthcare workers, the absolute numbers affected following close contact with patients or co-workers was higher than the absolute numbers following close contact with persons outside work with COVID-19. Comparable patterns of increased risks of loss of taste and smell were seen for all three types of COVID-19 contact. Participants reported high but not complete day-to-day compliance with PPE guidelines.

Strengths and limitations

Strengths of this study are the follow-up design with day-to-day information that allowed precise account for incubation period and daily change in exposure, the complete follow-up for PCR test results, and information on incident loss of taste and smell that was a key symptom of SARS-CoV-2 infection (22). During spring 2020, in this population, persistent loss of taste and smell was strongly associated with a positive PCR test for SARSCoV-2 with an odds ratio of 57.16 (95% CI 16.71-195), corresponding with a specificity of 98% and a positive predictive value of 84% (16). Other strengths are the free access to PCR testing and the high testing rate. The decision to be PCR tested was therefore unlikely to be strongly associated with COVID-19 contact and result of the PCR test, and we regard collider bias a minor problem (23).

Participants reporting one type of close COVID-19 contact (patients, co-workers or persons outside work) more often experienced the other types of contact and the mutually adjusted IRR estimates were substantially reduced and are expected to provide the best estimates of the separate effects, supported by our finding in the direct comparison between the three types of contact.

Participants with close COVID contacts had been PCR tested for SARS-CoV-2 infection more often than those with no such contacts. However, earlier PCR tests (all negative) should not be causally associated with SARS-CoV-2 infection as detected by a positive PCR test on a given day of follow-up but may be indicators of unobserved risk factors of SARS-CoV-2 infection that may confound associations. Our analyses indicated no such confounding. Furthermore, analyses of loss of taste and smell, which is a key symptom of SARS-CoV-2 infection unaffected by PCR testing frequency, showed results in line with those seen for SARS-CoV-2 infection.

Participants were about five years older than the invited population. The risk of SARS-CoV-2 infection has been suggested to increase with age, but we previously observed the highest SARS-CoV-2 sero-prevalence among the young participants of 18 000 healthcare workers from the source population of this study (24, 25). Participation was higher among healthcare workers from departments with less frequent patient contact, and we thus have no obvious explanation for the slightly higher incidence rate of SARS-CoV-2 infection in the study compared to source population.

Analyses were mutually adjusted for other COVID19 contact forms, sex, age, month and number of PCR tests. The likelihood of exposure to patients and coworkers with COVID-19 varied across departments and occupations, but because we had individual information on contact with patients and co-workers with COVID-19 for each day of follow-up, department and occupation were not included in the adjusted models.

COVID-19 contact information was partly obtained after the results of the PCR test results were available for the tested participants, which may have introduced recall bias and inflated results. However, sensitivity analyses relying only on contact information obtained before results of the PCR tests were available indicated no substantial recall bias. Knowledge of PCR test results as well as COVID-19 contact may, on the other hand, have inflated results for loss of taste and smell.

Being classified with no close COVID-19 contact during the 5-day exposure window allowed missing information for two of the five days. Because there may have been COVID-19 contact during these days, this may have attenuated IRR.

Our study population included mainly hospital healthcare workers, and findings may be less representative for healthcare workers in primary care because overall incidence of SARS-CoV-2 infection has been reported lower for general practitioners (3.50%) and nursing home staff (3.92%) than for hospital workers (5.32%) when the second wave of the pandemic peaked in Denmark in December 2020 (26).

Comparisons with other studies

Numerous studies during the last two years have documented increased risk and mortality of COVID-19 as well as hospitalization among healthcare workers as shown by several reviews (4, 6, 16). Lower risk for healthcare workers during the second than the first wave of the pandemic has been shown (27).

This study showed an overall SARS-CoV-2 infection rate of 30.9 per 100 000 person-days during the second wave, which was well below the self-reported positive PCR testing rate of 132 per 100 000 person-days observed in a prospective cohort of frontline healthcare worker during the first wave by Nugyen et al (2). Our observed infection rates of 153.7 and 240.8 per 100 000 person-days following contact with patients and colleagues with COVID-19 were, however, slightly higher than the infection rates of about 90 and 70 per 100 000 person-days reported by Mo et al (7) for healthcare workers with similar contacts at UK hospitals during the first wave. On the other hand, Nguyen et al (2) reported a higher infection rate of 553 per 100 000 person-days following contact with COVID-19 patients for healthcare workers reporting that they always had the PPE they needed (with no further specification). We observed a SARS-CoV-2 infection rate of 728.1 per 100 000 person-days following close contact with persons outside work with COVID-19, which was half the average household infection rate of 1660 per 100 000 person-days reported for the first wave (12). This may partly reflect that we included any close contact with a person outside work with COVID-19 and not only household contacts that are expected to be closer and last longer.

Several serological studies have provided results in line with ours for contact with patients (8-11), co-workers (8, 9) and persons outside work with COVID-19 (8, 9, 12-15). But there are also findings of no association (13-16).

The findings of these studies are, however, not directly comparable because of differences in population compositions, background incidence rates, definitions of COVID-19 contact and SARS-CoV-2 infection. We are not aware of other studies comparing the incidence rates of SARS-CoV-2 infection following exposure to patients or co-workers at work with persons outside work with COVID-19.

During a 17-day period around New Year 2021, a subset of the healthcare workers of the current study had used a new respirator with frequent defects during contact with COVID-19 patients that may partly have contributed to the increased risk we observed (28).

Concluding remarks

During the second wave of the pandemic, this healthcare worker population was at increased risk of SARS-CoV-2 infection when in close contact with patients and colleagues with COVID-19, but the risk was not as high as after contact with persons outside work with COVID19. However, the absolute numbers affected following contact with patients and co-workers were higher than the absolute numbers affected following COVID-19 contact outside work. PPE was not in shortage in the healthcare sector, guidelines for PPE use and other infection control measures were implemented but did not include a fit test. Compliance with required PPE was high but not complete.

The current findings thus stress the need for increased focus on use of recommended PPE, correct donning, doffing, fit test and other procedures (18, 29-31), training (32) and ventilation (33). The aim is to secure healthcare workers' health and reduce transmission into the community (34) during ongoing and future waves of SARS-CoV-2 and other infections.

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The authors declare no conflicts of interest.

Sidebar

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DETAILS

Subject:	Pandemics; Infections; COVID-19 vaccines; Personal protective equipment; Body mass index; Severe acute respiratory syndrome coronavirus 2; Regression analysis; Regression models; Disease control; Generalized linear models; Health care; Medical personnel; Questionnaires; Polymerase chain reaction; Disease prevention; COVID-19; Viral diseases; Medical supplies; Statistical analysis; Immunization; Coronaviruses; Patients; Occupational health; Masks; Respiratory diseases; Health risks; Disease transmission
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Night and shift work characteristics and incident ischemic heart disease and atrial fibrillation among healthcare employees - a prospective cohort study

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ABSTRACT (ENGLISH)

Objective This study aimed to examine the effects of various aspects of night and shift work on the risk of incident ischemic heart disease (IHD) and atrial fibrillation (AF) using detailed and registry-based exposure data. Methods This prospective cohort study included >30 300 healthcare employees (eg, nurses, nursing assistants) employed for at least one year in Region Stockholm 2008-2016. Information on daily working hours was obtained from a computerized administrative employee register and outcomes from national and regional registers. Using discrete-time proportional hazard models, we analyzed the outcomes as functions of working hour characteristics the preceding year, adjusted for sex, age, country of birth, education, and profession. Results We observed 223 cases of IHD and 281 cases of AF during follow-up 2009-2016. The risk of IHD was increased among employees who the preceding year had permanent night shifts compared to those with permanent day work [hazard ratio (HR) 1.61, 95% confidence interval (CI) 1.06-2.43] and among employees working night shifts >120 times per year compared to those who never worked night (HR 1.53, 95% CI 1.05-2.21). When restricted to non-night workers, the risk of IHD was increased for employees having frequent quick returns from afternoon shifts. No increased risks were observed for AF. Conclusions Night work, especially working permanent night shifts and frequent night shifts, is associated with an increased risk of incident IHD but not AF. Moreover, frequent quick returns from afternoon shifts (among nonnight workers) increased IHD risk. Organizing work schedules to minimize these exposures may reduce IHD risk.

FULL TEXT

Headnote

Objective This study aimed to examine the effects of various aspects of night and shift work on the risk of incident ischemic heart disease (IHD) and atrial fibrillation (AF) using detailed and registry-based exposure data.
Methods This prospective cohort study included >30 300 healthcare employees (eg, nurses, nursing assistants) employed for at least one year in Region Stockholm 2008-2016. Information on daily working hours was obtained from a computerized administrative employee register and outcomes from national and regional registers. Using discrete-time proportional hazard models, we analyzed the outcomes as functions of working hour characteristics the preceding year, adjusted for sex, age, country of birth, education, and profession.
Results We observed 223 cases of IHD and 281 cases of AF during follow-up 2009-2016. The risk of IHD was increased among employees who the preceding year had permanent night shifts compared to those with permanent day work [hazard ratio (HR) 1.61, 95% confidence interval (CI) 1.06-2.43] and among employees working night shifts >120 times per year compared to those who never worked night (HR 1.53, 95% CI 1.05-2.21). When restricted to non-night workers, the risk of IHD was increased for employees having frequent quick returns from afternoon shifts. No increased risks were observed for AF.
Conclusions Night work, especially working permanent night shifts and frequent night shifts, is associated with an increased risk of incident IHD but not AF. Moreover, frequent quick returns from afternoon shifts (among nonnight workers) increased IHD risk. Organizing work schedules to minimize these exposures may reduce IHD risk.
Key terms arrhythmia; cardiovascular disease; coronary heart disease; night work; occupational exposure; occupational health; quick returns; register data; Stockholm; Sweden; work schedule.

Healthcare employees have shift work schedules involving irregular or unusual hours of work to provide services around-the-clock. Recent European data showed that about 40% of healthcare employees worked on shifts, such as permanent shifts of mornings, afternoons, or nights, alternating or rotating shifts, and 14% reported usual weekly working hours longer than the standard 40-hour workweek. Moreover, 23% of employees in all sectors combined had a short recovery time (<11 hours) between two shifts (1).

Cardiovascular diseases (CVD) and especially ischemic heart disease (IHD) are leading causes of morbidity and mortality worldwide (2). Atrial fibrillation (AF) is the world's most common heart rhythm disorder, associated with increased morbidity and mortality. AF is one of the leading risk factors for ischemic stroke and is also associated with developing heart failure and dementia (3, 4). Both IHD and AF share many of the same risk factors, such as increased age, obesity, hypertension, and physical inactivity (5). Shift work has been hypothesized to increase the risk of chronic diseases like CVD through several pathways including circadian rhythm disruption, which may affect glucose and lipid metabolism, appetite regulation, inflammation, hormone secretion, hypertension, atherosclerosis, and autonomic nervous system imbalance (6-8). In addition, shift workers may have poorer psychosocial working conditions, such as job strain and social stress (6, 9), and poorer lifestyle behaviors, such as poor diet, physical inactivity, and smoking habits compared to non-shift workers (9-11), which can, in turn, increase the risk of CVD.

Previous studies of the association between shift work, long working hours, and the risk of CVD mostly focused on IHD and have been summarized in several systematic reviews and meta-analyses (12-17). The first systematic review of 16 epidemiological studies by Frost et al (12) found limited epidemiological evidence for a causal relationship between shift work, mainly evening, night, and rotating shift work, and the risk of IHD. In a recent meta-analysis of 31 independent results, Cheng et al (17) found a pooled risk ratio of 1.13 [95% confidence interval (CI) 1.08-1.20] for IHD. However, data on the association between night and shift work and AF are very limited. AF episodes follow a circadian rhythm and occur most commonly in the early morning and the early evening hours (18). A recent cohort study of the UK Biobank population shows that self-reported night shift work of >10 years and working an average of 3-8 nights per month increased the risk of AF (19). Kivimäki et al (20), in a prospective multi-cohort study reported that those working >55 hours per week had an approximately 40% higher risk of AF than those working a standard 35-40-hour work week. However, in both studies, working hour information was self-reported and assessed at the baseline only, which may lead to both differential and non-differential misclassification of the exposure. Relying on self-reported information on working hours or lack of longitudinal exposure information is also a major limitation of several of the aforementioned studies on shift work and CVD. Further cohort studies of shift workers have been recommended to use detailed and more precise exposure information on working hours and hereby overcome the limitations related to exposure assessment in prior studies (21-23). Therefore, in the present study, we used registry-based exposure data from a computerized HR administrative system, including detailed individual information on working hours day-by-day for all participants in a cohort of healthcare employees in Stockholm. This study aimed to examine the effects of various aspects of night and shift work on the risk of incident IHD and AF in a prospective design.

Methods

Study design and participants

This study is a prospective cohort study of healthcare professionals who were employed in in- or outpatient care services for at least one year anytime between 1 January 2008 and 31 December 2016, identified from a computerized administrative employee register (HEROMA) in Region Stockholm, Sweden. We restricted the study to employees in Region Stockholm who often work night shifts, which includes nurses, including midwives, nursing assistants, or related professions (eg, accommodation assistants, caregivers, personal assistants) (N=30 602). Physicians were not included in the present analysis due to less detailed information on working hours and night work. From the total 30 602 participants, we created an analytical subsample investigating the risk of IHD by excluding 204 employees with a previous diagnosis of IHD before the first employment day (based on data back to 1998) or within the first 12 months of employment. Correspondingly in the AF subsample, we excluded 127 employees with a previous AF diagnosis before the first employment day or within the first 12 months of employment. Thus, the final samples comprised 30 398 participants (26 624 women and 3774 men) in the IHD cohort and 30 475 participants (26 680 women and 3795 men) in the AF cohort. A flowchart for the inclusion and exclusion procedure for both IHD and AF cohorts is presented in figure 1.

Assessment of exposure

HEROMA in Region Stockholm provided information on working hours. We collected detailed individual information on working hours day-by-day for all employed between 1 January 2008 and 31 December 2016, including information on the occupation for each working period. For each working shift, there is information on the exact start- and end times. We excluded work shifts with a duration of <4 hours (0.7%). The method for aggregation and characterization of working time patterns based on register-based working hours for healthcare employees was previously evaluated in Finland (24), and was described specifically for HEROMA in our two studies investigating shift and night work and the risk of cerebrovascular disease (25) and preterm birth (26).

Classification of exposure

Detailed information on the exposure classification has been described previously (25). Briefly, based on all work schedules, three types of shifts were identified: day shifts (starts after 06:00 and ends no later than 18:00); afternoon shifts (starts after 12:00 and ends later than 18:00, but not a night shift); and night shifts (>3 hours of work within 22:00-06:00). Furthermore, the cohort participants were, for each year, classified as (i) permanent daytime workers, (ii) persons working daytime and afternoon shifts but not night shifts, (iii) persons working various shift types including night shifts, and (iv) persons working permanent night shifts. The exposure classification was assessed annually to consider variations over time.

For each year, the cut-off points in classifying exposures were chosen based on 1-25th, 25th-50th, 50th-75th and >75th percentile in the distribution of the exposed group. Thus, we calculated the frequency of night shifts, quick returns from night shifts (<28 hours between the end of a night shift and the beginning of the following shift), and quick returns from afternoon shifts (<11 hours between the end of an afternoon shift and the beginning of the following shift) per year. Regarding long working hours, we calculated the frequency of long (>45 hours) working weeks per year. We also conducted analyses based on continuous measures (test for trend).

Assessment of the outcome

Incident IHD and AF events were defined as the first occurrence of events as described by the International Classification of Diseases, tenth revisions (ICD-10); IHD (ICD: I20-25), and AF or atrial flutter (ICD: I48). The national patient register at the National Board of Health and Welfare (inpatient and specialized outpatient care) and the regional database from general practice in Stockholm (VAL database) provided data on IHD and AF. The VAL database records the diagnoses of non-hospitalized patients from both inpatient care and outpatient contacts within the Region Stockholm. We included the IHD or AF diagnosis that appeared first in either of the two registers, during the follow-up period between 1 January 2009 and 31 December 2016. The employees were at risk from one year after the start of employment until diagnosis, death, or end-of-follow-up, whichever came first.

Covariates

Information on age, sex, education, and country of birth was obtained from the register of the total population at Statistics Sweden.

Data analysis

To examine the effect of different types of shift characteristics on the risk of IHD and AF, we used discrete-time proportional hazard models, stratifying the person-time experience of the cohort by follow-up year, starting the assessment of risk one year after the first employment day (27). In the estimations of hazard ratios (HR), we adjusted for several factors that might affect the risk, such as age (continuous), sex, education (higher education (university >3 years), upper secondary or elementary school or less), country of birth (Sweden, Nordic countries except Sweden, Europe except Nordic countries, other countries) and profession (nurses including midwives, nursing assistants or other related professions). Moreover, country of birth was adjusted for as a proxy measure for ethnicity, and educational level and profession were adjusted for as a proxy for socioeconomic status. Age and exposure variables were treated as time-dependent variables updated for each year of follow-up, whereas sex, education, country of birth, and profession remained the same during all the follow-up years. Additionally, some analyses were also adjusted for the number of total night shifts per year in order to disentangle the effect of intensity of night work in general from the effect of working consecutive night shifts or having quick returns from night shifts.

We estimated HR with 95% CI in the association between different shift work characteristics and incident IHD and AF. For the exposure "type of shift work", the comparison was with those who always worked day shifts. For night shift characteristics ("frequency of night shifts", "frequency of >3 consecutive night shifts" and "quick returns (<28 hours) from night shifts") the comparisons were with employees who never worked night shifts (those who worked day and/or afternoon shifts but no night shifts). For "quick returns (<11 hours) from afternoon shifts" the analyses were restricted to those who never worked nights and the comparison was with those who never had quick returns. For "frequency of long (>45 hours) working weeks" the comparison was with those who never worked long working weeks (only working weeks of <40 hours). The estimated HR were always based on the exposure/shift work characteristics during the year preceding the outcome. We also performed trend tests, using the arithmetic average of the number of times (frequency) in each exposure category as a continuous variable in the regression model. The trend tests assessed the risk increases per ten additional times of the different aspects of night and shift work and long working weeks, such as ten additional times of night shifts.

We used SAS software, version 9.4 for Windows (SAS Institute Inc, Cary, NC, USA), with the statistical association at $P<0.05$ for all statistical analyses.

Results

The baseline characteristics of the study participants at the inclusion year, according to the work schedules for the IHD cohort, are presented in table 1, and in supplementary material, www.sjweh.fi/article/4045, table S1 for the AF cohort. The baseline characteristics are based on the information from the inclusion year, but the work schedules are based on information from all the years the participants worked between 2008-2016. There were 6860 (22%) employees with permanent daytime work during the whole employment period, 11 181 (37%) employees with at least one afternoon shift (no night shifts), 11 240 (37%) employees with at least one night shift (excluding those working night only) and 1117 (4%) with permanent night shifts during the whole employment period. Compared with day workers, participants who were engaged in shift work with or without night shifts, or permanent night shifts, were more often men and from a country of birth outside the Nordic countries. Moreover, employees working shifts with or without night shifts were more often younger compared with day workers or permanent night workers. The proportion of nurses was highest among day workers and the proportion of nursing assistants was highest among permanent night workers (table 1).

The 30 398 participants in the IHD cohort and the 30 475 participants in the AF cohort contributed to a total of 211 144 and 211 546 person-years, respectively. We observed a total of 223 incident IHD cases and 281 incident AF cases during up to eight years of follow-up 2009-2016. Of 223 cases of IHD, 175 were first identified from the national patient register and 48 cases from the regional VAL database. Of 281 cases of AF, 201 were first identified from the national patient register and 80 cases from the regional VAL database. The IHD cases included 76 cases of acute myocardial infarction, 124 cases of stable or unstable angina pectoris, and 23 cases of other IHD. The AF cases included 190 cases of paroxysmal or chronic AF and 91 cases of other AF and/or atrial flutter.

Type and frequency of night work and risk of IHD and AF

Working permanent night shifts was associated with an increased risk of IHD the following year compared to those with permanent day work during the preceding year (HR 1.61, 95% CI 1.06-2.43) (table 2). The risk for IHD was higher among those who frequently worked night shifts (>120 times per year: HR 1.53, 95% CI 1.05-2.21), and who frequently worked >3 consecutive night shifts (15-20 times per year: HR 1.85, 95% CI 1.14-2.98), compared with those with no night work during the preceding year. The trend test indicated an increasing risk for IHD with increasing number of night shifts, expressed as risk per 10-night shifts (HR for beta 1.03, 95% CI 1.00-1.05) and with increasing 10 spells of >3 consecutive night shifts (HR for beta 1.06, 95% CI 1.00-1.20). That is, for every 10 additional night shifts and 10 additional spells of >3 consecutive night shifts, the risk for IHD increased by 3% and 6%, respectively (table 2). However, for spells of >3 consecutive night shifts, the increased risks were attenuated after additional adjustment for the total number of night shifts (table 2). All compari- sons between type and frequency of night work and associations with AF demonstrated no increased risk in the adjusted model, also after additional adjustment for the total number of night shifts (table 3).

Quick returns and the risk of IHD and AF

Employees who frequently had quick returns (<28 hours) from night shifts had no significantly increased risk for IHD (HR 1.35; 95% CI 0.87-2.10) comparing >71 times per year to those with no night shifts. The trend test indicated that every ten additional quick returns from night shifts increased the risk for IHD by 4% (HR for beta 1.04, 95% CI 1.00-1.08). However, after additional adjustment for the total number of night shifts, the trend was attenuated (table 2). Analyses restricted to those who never worked night showed that employees with frequent quick returns (<11 hours) from afternoon shifts had an increased risk for IHD (HR 1.68; 95% CI 1.04-1.71) comparing >56 times per year to those with no quick returns. The trend test indicated an increasing risk for IHD with increasing ten times of quick returns from afternoon shifts (HR for beta 1.04, 95% CI 1.00-1.10). That is, for every ten additional quick returns from afternoon shifts, the risk for IHD increased by 4% (table 2). All comparisons between quick returns from night shifts or quick returns from afternoon shifts and associations with AF demonstrated no increased risk in the adjusted model, also after additional adjustment for the total number of night shifts (table 3).

Long working weeks and the risk of IHD and AF

There was no statistically significant increased risk for IHD and AF among employees who often (>11 times per year) had long working weeks (>45 hours), compared to those with working weeks of <40 hours, and there was no trend of increasing risk estimates with the increasing number of times of long working weeks (table 2 and 3). However, the trend test indicated a decreasing risk for AF with increasing 10 times of long working weeks (HR for beta 0.69, 95% CI 0.51-0.92) (table 3).

Discussion

In this prospective cohort study with registry-based exposure information, we observed an excess risk of incident

IHD among healthcare employees who during the preceding year worked permanent night shifts, compared to those with permanent day work. There was also an excess risk of IHD among employees who worked night shifts >120 times during the preceding year compared to those with no night work, supported by a dose-response pattern. We also observed an excess risk of IHD related to frequent (15-20 times the preceding year) spells of >3 consecutive night shifts, but this effect was attenuated after additional adjustment for the total number of night shifts (to disentangle the effect of many nights from the effect of many consecutive nights). These findings suggest that the observed excess risk of IHD related to frequent spells of >3 consecutive night shifts, is more due to intensive night work per se and not specifically consecutive night work.

We acknowledge a certain degree of overlap between exposure groups, where permanent night workers are most likely overrepresented in the highest exposure groups. Therefore, the increased IHD risk for the highest exposure group of eg, "frequency of night shifts" may probably largely be attributed to intensive permanent night work. However, the group "night shifts only" also comprise employees with part-time work who are not necessarily part of the highest exposure groups.

There was no significant excess risk of IHD concerning frequent long working weeks of >45 hours. Among non-night workers we observed an excess risk of IHD related to frequent (>56 times the preceding year) quick returns (<11 hours) from afternoon shifts.

For "frequency of night shifts" the exposure group >120 times per year corresponded to a mean of 142 nights per year. In terms of night shifts per month, this would correspond to an average of >10 nights per month and a mean of 12 nights per month. For "quick returns from afternoon shifts" the exposure group >56 times per year corresponded to a mean of 70 times per year. This would similarly correspond to an average of >5 quick returns from afternoon shifts per month and a mean of 6 quick returns per month.

We did not observe any significant excess risk of AF related to any of these night and shift work patterns or long working hours. Instead, there was a trend of decreasing risk of AF with increasing frequency of long working weeks, which may reflect a healthy worker effect.

We are not aware of any earlier studies on the association between registry-based specific working hour characteristics and the risk of incident IHD but our results are in agreement with previous reviews and meta-analyses linking self-reported working hour data to the risk of IHD (13, 15, 17). For example, the metaanalysis by Cheng et al (17) suggested an association between the risk of IHD and increasing duration of shift work, supported by a positive dose-response pattern. Vyas et al (13) in a pooled subgroup analysis, reported the highest increase in IHD risk (41%) for employees with permanent night shifts. In the present study, we also found the highest risk of IHD (61%) associated with permanent night shift work and our results indicate that the intensity of night work, in general, is of most importance for the IHD risk. In a recent evaluation (review of reviews) by Rivera et al (28) the quality of the epidemiologic evidence between shift work (defined as any work outside the standard daytime work hours) and health conditions, was estimated as low for IHD and myocardial infarction and very low for events of CVD overall. However, their evaluation did not differentiate between evidence for different types of shift work, various intensity of shift work or for night work specifically. In the present study the association with IHD risk was strongest for intensive night work.

Some possible biological mechanisms may explain the association between night and shift work and IHD risk. The classic opinion proposes that circadian dis- ruption caused by shift work results in the desynchronization of endogenous and exogenous components and disturbances of the cardiovascular system (29). It has also been proposed that shift work is associated with increased psychosocial stress (6, 9), leading to hypersecretion of cortisol and catecholamines, which may contribute to disorders increasing the risk for IHD. Furthermore, smoking, physical inactivity in leisure time, changes in appetite-regulating hormones and other factors leading to an unhealthy diet and being obese, increased alcohol consumption, the likelihood of ignoring symptoms of disease, elevated blood lipids, and high blood pressure are some underlying factors that have been suggested to be involved in the association between shift work and IHD (9-11). Sleep deprivation and insufficient recovery, related to consecutive night shifts and quick returns, could be another possible pathway from night shift work to the increased risk of IHD. Several epidemiological and experimental studies including female hospital employees found that the number of consecutive night shifts was associated with progressive changes in hormones involved in circadian rhythms, such as melatonin and cortisol, and heart rate variability (30-32), and thereby might increase the risk of IHD. In the previous studies, working >3 consecutive night shifts was associated with a decrease in melatonin among hospital employees in Canada (30) and Denmark (32). Furthermore, a prospective, longitudinal study of hospital nurses suggests that nurses must be allowed more than two days off work on changing from night shifts to other shifts to adjust their circadian rhythms of salivary cortisol levels (33). Our findings suggest that the intensity of night shifts, in general, seems to be a more decisive factor behind the increased risk of quick returns from nights shifts than the number of consecutive shifts. However, in our previous study based on the same cohort as in the present study, the risk of incident cerebrovascular disease was more influenced by consecutive night shift work per se (25). In the present study, we also found an association between a short recovery time (<11 hours) after the afternoon shifts and IHD among non- night workers. A short recovery time between the shifts is associated with increased sleepiness and a higher level of perceived stress (13), insulin resistance (6), and activation of the immune system with the result of inflammation (34), which in turn may contribute to the development of IHD. Furthermore, a prospective study suggests that incomplete recovery from work is an aspect of the overall risk profile of CVD mortality among industrial employees (35).

Our study did not observe any association between frequent long working weeks (>45 hours) and the risk of IHD. However, our study does not rule out an elevation of IHD risk associated with frequent very long working weeks. A recent meta-analysis observed an association between working on average >55 hours per week and IHD (16). Due to the small sample size in the category of frequent long working weeks of >55 hours, our study lacked the power to analyze it.

Our results do not support the findings of the previous study by Wang et al (19) that employees with permanent night shifts and working an average of 3-8 nights per month increase the risk of incident AF. In their study, the exposure information was self-reported and assessed at the baseline only which could explain some of the differences in the results. It is intriguing though that we could observe an effect of night shift work on IHD but not AF. These outcomes share several similar risk factors, but our results indicate that the risk of AF is not affected in the same way by intensive night shift work.

In this study, we chose a time window of one year for the exposure, to compromise between acute and chronic effects on IHD and AF. However, this time window does not exclude those employees who may have belonged to other exposure groups previously, since the exposure classification was updated annually to account for variations over time. The one-year time window reflects the exposure from a combination of acute working time triggers the previous year and cumulative demanding working times, since the employees may have worked in a similar way in previous years.

Strengths and limitations

The main strength of this study is very detailed registrybased data on working hours during the employment period. The data was not from the employees themselves, which avoids the risk that people forget details about their working hours back in time. Thus, our study was not biased by self-reported and/or retrospective estimations. Another strength is that data on health outcomes are retrieved from registers of good quality and that the cohort consists of employees in the healthcare sector where the percentage of shift and night workers is high. Moreover, healthcare employees represent a homogeneous group with less variability in potential confounders related to socioeconomic position. We had a coverage of cases from both in- and outpatient hospital care services and also from outpatient visits at the regional general practice in Stockholm.

Some limitations include a lack of information on important lifestyles and other individual risk factors associated with IHD and AF, such as smoking habits, physical inactivity, hypertension, and diabetes, that can act as confounders or mediators. We also lacked information on physical and mental workload, such as the possibility of sleep during on-call shifts, and on chronotype and personal work hour preferences of the participants. Our study includes only healthcare employees, with the majority having constantly chang- ing schedules over the employment period.

Therefore, our results may not apply to populations with other occupations. Additionally, we did not account for the possible healthy worker effect, which would underestimate the actual risk. Employees with health problems may need to reduce their work intensity over time or be transferred from night to day work.

Concluding remarks

In this prospective cohort study of >30 300 healthcare employees with registry-based data on working hours, we found that intensive night work, especially working permanent night shifts and frequent night shifts is associated with an increased risk of incident IHD but not AF. Among non-night workers, we observed an excess risk of IHD related to frequent quick returns from afternoon shifts.

These findings add to previous observations from this cohort which suggest that there is an increased risk of preterm birth and cerebrovascular disease in relation to intensive night work, especially working many spells of consecutive night shifts and short recovery after night shifts. When healthcare employees are engaged in night work, their health might benefit from avoidance of permanent night shift work, a restriction of the total number of night shifts per year, and an adequate recovery time after any shift. Ideally, future studies on night work in relation to IHD and AF should include other occupational groups and combine objectively measured working hours and personal characteristics like chronotype and working hour preferences, as well as working conditions (eg, workload).

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Sidebar

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Chronic disorders, work-unit leadership quality and long-term sickness absence among 33 025 public hospital employees

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ABSTRACT (ENGLISH)

Objective This study aimed to examine the association between work-unit level leadership quality and individual-level long-term sickness absence (LTSA) in the hospital sector and effect modification by chronic disorders. Methods This longitudinal analysis included 33 025 Danish public hospital employees who were followed-up for one year after baseline in March 2014. Leadership quality was assessed by questionnaire with mean responses aggregated by work-unit and characterized in tertiles. LTSA during follow-up was determined from employer records. Chronic disorders at baseline was assessed from the Danish hospital and prescription registers. We performed multilevel logistic regression to estimate odds ratios (OR) and 95% confidence intervals (CI) adjusting for potential confounders. We evaluated interaction between chronic illness and low leadership quality on multiplicative and additive scales. Results We identified employees as healthy (60.8%) or with somatic (31.6%), mental (3.3%), or both somatic and mental (4.3%) disorders. During follow-up, 6% of employees registered a LTSA. Medium and high leadership quality were associated with lower risk of LTSA with OR of 0.84 (95% CI 0.76-0.94) and 0.73 (95% CI 0.65-0.82) respectively, compared to low leadership quality. Associations were similar for healthy employees and employees with only somatic disorders, whereas no association was observed for employees with mental disorders (in presence or absence of somatic disorders). No statistically significant (a=0.05) interactions between leadership quality and chronic disorders on LTSA were observed. Conclusion The findings suggest that the quality of leadership in work units is associated with risk of long-term sick leave in the Danish public hospital sector and that strong leadership protects employees against LTSA.

FULL TEXT

Headnote

Objective This study aimed to examine the association between work-unit level leadership quality and individual-level long-term sickness absence (LTSA) in the hospital sector and effect modification by chronic disorders. Methods This longitudinal analysis included 33 025 Danish public hospital employees who were followed-up for one year after baseline in March 2014. Leadership quality was assessed by questionnaire with mean responses aggregated by work-unit and characterized in tertiles. LTSA during follow-up was determined from employer records. Chronic disorders at baseline was assessed from the Danish hospital and prescription registers. We performed multilevel logistic regression to estimate odds ratios (OR) and 95% confidence intervals (CI) adjusting for potential confounders. We evaluated interaction between chronic illness and low leadership quality on multiplicative and additive scales. Results We identified employees as healthy (60.8%) or with somatic (31.6%), mental (3.3%), or both somatic and mental (4.3%) disorders. During follow-up, 6% of employees registered a LTSA. Medium and high leadership quality were associated with lower risk of LTSA with OR of 0.84 (95% CI 0.76-0.94) and 0.73 (95% CI 0.65-0.82) respectively, compared to low leadership quality. Associations were similar for healthy employees and employees with only somatic disorders, whereas no association was observed for employees with mental disorders (in presence or absence of somatic disorders). No statistically significant (a=0.05) interactions between leadership quality and chronic disorders on LTSA were observed. Conclusion The findings suggest that the quality of leadership in work units is associated with risk of long-term sick leave in the Danish public hospital sector and that strong leadership protects employees against LTSA.

Key terms absenteeism; chronic disease; longitudinal study; managerial quality; occupational health; psychosocial

work resource.
The general workforce population is aging; the proportion of older workers aged 55-64 years is increasing and is projected to equal one quarter of the global workforce by 2030 (1). To maintain labor market participation among workers, many high-income countries are regulating pension schemes to increase the retirement age which will also lead to a higher proportion of older-aged individuals, and those with chronic health conditions or disorders, in the work force (2). In Denmark, approximately 35% of workers in 2013 were reported to have at least one chronic disorder (3).
Workers with chronic disorders generally have a weaker connection to the labor market. Studies in Europe including Denmark have shown that workers with chronic disorders have lower employment rates (4) and higher rates of long-term sickness absence (LTSA) (5-7) in comparison with healthy workers. The previous studies examined chronic disorders that included a wide range of chronic somatic and/or mental health conditions (5, 6), some of which may show no visible symptoms (eg, hypertension, certain autoimmune disorders). The importance of workplace resources may prove particularly relevant for workers with chronic disorders. For example, the handling of health-related matters during work and adaptation of work tasks may affect the risk and length of sick leave and retention in the labor market. Leadership quality (LQ), or quality of management or supervision, may be considered a workplace psychosocial resource that can help improve labor market participation among workers. LQ refers to specific behaviors or actions of a leader (eg, manager or supervisor) towards their subordinates including the ability to provide guidance, solve conflicts, plan and organize work, prioritize job satisfaction, or support career development (8, 9). Epidemiologic evidence from single and multi-occupational sector studies support the association between LQ with a range of indicators of labor market participation including retention (10), sickness absence (SA) (11-17), and early exit from the labor market (17, 18). Many of the previous studies relied on self-reported LQ at the employee level only, which may lead to reporting bias should workers with chronic disorders have a higher tendency to report a negative work environment.
Better LQ in an employee's work unit may be hypothesized to be beneficial for employees with chronic disorders as greater openness and flexibility around needs and better organization, help, and support around work tasks have a positive impact. However, whether LQ is similarly or more or less beneficial for workers with chronic disorders and their participation in the labor market is not known. Only a few populationbased studies from The Netherlands and UK examined whether chronic disorders modify the association between psychosocial working conditions and resources, sometimes inclusive of leadership/managerial quality, and labor market participation indicators (6, 19-21), but they either objectively assessed only a few specific chronic diseases or relied on self-reported assessment on a wider scope of chronic disorders.
Countering for the methodologic limitations of previous studies that either examined individual-level LQ or included self-reported or limited scope of chronic disorders, the present study aims to investigate if higher LQ at the work-unit level is associated with lower occurrence of LTSA in a large prospective cohort study of hospital employees in Denmark (22). By leveraging the Danish hospital patient registers and prescription registers for objective assessment on a wide range of chronic somatic and mental disorders in the study population, we also evaluated whether the association between work-unit LQ and LTSA is modified by the presence of chronic somatic or mental disorders.

Methods

Study population and design

This longitudinal analysis is nested within the Well Being in HospitAL Employees (WHALE) study, an ongoing prospective observational cohort study including all public hospital employees within the Capital Region of Denmark (23). In brief, 37 720 public hospital employees in the Capital Region were invited for a well-being assessment survey in March 2014, of whom 84% participated. Employees' information on SA and on sex, institution, department, work-unit and professional sector was obtained from employers' records. Participants were followed up starting on 1 April 2014 for a maximum of 12 months after the date of participation in the 2014 survey or until termination of employment (ie, early/old-age retirement, leaving the workplace, unemployment), which ever came first. A previous analysis of employees who completed the 2014 WHALE survey showed that 10.5% of employees exited from work within 12 months following the survey (10), thus we did not expand the period of follow-up. Because we aggregated LQ at the work-unit level, employees who did not respond to the questionnaire remained in the study sample if all other inclusion criteria were met. A total of 33 025 employees (87.6%) who were nested in 2272 work units were included in this analysis and had complete information on SA records, work-unit LQ, and employee-level and work-unit characteristics; a detailed flowchart of study participation and inclusion can be found in the online supplementary material (www. sjweh.fi/article/4036, figure S1).

Work-unit leadership quality

LQ was measured using four questions that were adapted from the Interpersonal Relations and Leadership dimension of the validated Copenhagen Psychosocial Questionnaire II (23) using items from the recognition scale, quality of leadership scale, and social support from supervisor scale, and addressed concepts such as recognition, organization of work, support and prioritization of well-being. These questions begin with "To what degree and end with is your work recognized and appreciated by your manager?", ". is your manager good at organizing work in your workplace?", "... do you get help and support from your manager when you need it?", and ". would you say that your manager prioritizes job satisfaction?" The response scales were 5-point Likert scale ranging from 'not at all' to 'to a very high degree'. The Cronbach's alpha coefficient of the four items was 0.91. Individual-level LQ was assessed by calculating the mean of the item responses in percentages and converting these into a scale ranging from 0-100, with higher scores representing higher LQ. Individual-level LQ was recorded as missing if the employee responded to only one of the items. Workunit LQ was further calculated as the aggregated mean of individual-level LQ within each work-unit, and that value was assigned to all employees within the corre- sponding work unit. Work-unit LQ was treated as missing if individual-level data were available for <50% of eligible employees at the unit level. Work-unit LQ was characterized as both continuous linear and in tertile categories (low, medium, high).

Chronic somatic and mental disorders

Employees with chronic disorders, understood as longterm or recurrent illness, are defined as those who were hospitalized with or under continuous treatment with prescription medication for one of 13 chronic diseases (cancer, endocrine diseases including diabetes, neurological diseases, eye and ear diseases, cardiovascular diseases, chronic lung diseases, diseases of the digestive system, diseases of the skin, musculoskeletal diseases, chronic pain, kidney diseases, abdominal diseases, and mental illnesses). The chronic diseases were identified in the Danish registers based on previous work (5, 24) and in accordance with the International Classification of Diseases-10th edition (ICD-10) and Anatomic Therapeutic Chemical Classification System (ATC) codes. All chronic diseases were identified by either ICD-10 diagnosis for at least one hospital patient encounter in the Danish National Patient Registry (25) and the Danish Psychiatric Central Research Register (26), or by ATC codes for at least five prescription reimbursements in the Danish National Prescription Registry (27) within five years prior to the administration of the 2014 survey. Supplementary table S1 summarizes the list of the 13 chronic diseases and their corresponding ICD-10 and ATC codes. We constructed a composite chronic disorder variable consisting of four mutually exclusive categories: (i) healthy (ie, no somatic or mental disorders), (ii) only somatic disorders, (iii) only mental disorders, and (iv) both somatic and mental disorders and mental illness.

Long-term sickness absence

We obtained employees' SA information from the employers' payroll system, where SA including its length was registered on a monthly basis. Consistent with how SA episodes were registered in the payroll system, and with current Danish regulations regarding sickness benefits, LTSA was characterized as a binary variable (yes/no) and defined as a SA episode of >29 consecutive days that was initiated within one year following baseline. We also measured LTSA within one year prior to baseline.

Statistical analysis

Similar to methods described in Török et al (28), we used multi-level logistic regression to model LTSA with a random intercept for work-unit as a function of work-unit LQ, and with the Kenward-Roger degrees of freedom (approximation procedure (PROC GLIMMIX procedure, SAS v9.4). The employers' payroll system did not provide the exact dates of SA and therefore we used logistic rather than Cox regression. We fit models where work-unit LQ was characterized as continuous (per interquartile range unit increase in work-unit LQ) and as categorical tertile variables (medium, high, low tertile as reference). All models were minimally adjusted for age and sex before including adjustment for part-time work (<37 hours/week), seniority (number of years employed in the Capital region), job classification, work-unit size (total number of employees within workunits), and work-unit proportion of female and part-time employees. All associations were presented as odds ratios (OR) with 95% confidence intervals (CI). To infer the preventive potential of work-unit LQ, we calculated the population attributable fraction (PAF) to estimate the percentage of LTSA cases attributable to the exposure to the low and medium tertiles of work-unit LQ (29).

We evaluated interaction between work-unit LQ and chronic disorders on the multiplicative scale by including interaction terms between low and medium tertile categories of work-unit LQ and chronic illness indicators in the model; we set the significance level for interaction terms at $P < 0.05$. We also assessed additive interaction by calculating the relative excess risk due to interaction (RERI) (30) in the doubly adverse-exposed groups for only somatic illness (i.e. only somatic illness present, low tertile LQ) and mental illness (mental illness present, low tertile LQ). For ease of interpretation, the common reference category in this model was the subgroup of healthy employees in the high tertile of LQ.

As a sensitivity analysis, we examined the influence of prior LTSA as a potential confounding with two different analytical approaches. First, we included prior LTSA as an additional adjustment factor in the logistic regression model. Second, we restricted the sample to employees with no indication of prior LTSA. To address confounding by individual-level socioeconomic status, we also adjusted for household income and marital status, both variables derived from national registries. We additionally assessed the overall interaction between work-unit LQ and individual-level occupational groups to determine if the association between work-unit LQ and LTSA was consistent across occupational groupings. Finally, approximately 6.4% (N=2408) of all invited study participants were excluded from the analysis due to having missing information on either LTSA during following or work-unit LQ. We observed differences in the distributions of individual-level and work-unit characteristics between the excluded subset and the analysis sample (supplementary table S2), and we applied inverse probability weights to account for the potential selec- tion bias arising from this specific exclusion from the analysis sample (31).

Results

Baseline characteristics

Table 1 summarizes the employee-level and work-unitlevel characteristics of the 33 025 study participants at baseline as a pooled sample and by work-unit LQ tertiles. During the 1-year follow-up period, 6% of employees had a registered LTSA; 7.0%, 5.8% and 5.1% had a registered LTSA during follow-up among employees in the low, medium and high tertiles of workunit LQ, respectively. Overall, we observed relatively minor differences in the distribution of individual and work-unit-level variables between work-unit LQ tertile subgroups. However, work-unit LQ was inversely correlated with work-unit size. Supplementary figure S2 illustrates the distribution of LQ across work-units. The intraclass coefficient (ICC) for individual-level LQ at the work-unit level was 26% (ICC=0.261), indicating a moderate degree of clustering of LQ within work-units.

At baseline, we identified 20 081 (60.8%), 10 443 (31.6%), 1090 (3.3%) and 1411 (4.3%) of employees as healthy or with only somatic disorders, mental disorders, or both somatic and mental disorders, respectively (supplementary table S3). Of employees with both somatic and mental disorders, 12.8% had prior LTSA. The respective figures for those with only mental or somatic disorders were 8.2% and 7.6%, considerably higher than that of healthy employees (2.7%). A similar pattern was observed for employees who registered a LTSA during follow-up. Across the major chronic disorder subgroups, highest mean age and years of seniority was observed for employees with only somatic disorders. Employees with mental disorders (with or without somatic disorders) were most often female and part-time employees, and had the highest mean work-unit size and proportions of female and part-time employees in work-units. The subgroups of mental disorders were also very similar in distribution with respect to most individual-level and work-unit characteristics. The distributions of work-unit characteristics were similar between the healthy and only somatic disorder subgroup of employees. Overall, the distribution of job classifications was similar across the major chronic disorder subgroups. Among employees with only chronic somatic disorders, the most occurring subtypes were cardiovascular-related diseases (13.9%), musculoskeletal disorders (12.3%) and chronic pain (8.9%) (supplementary table S4).

Work-unit LQ and LTSA

Per interquartile range (15.6) increase in work-unit LQ score was associated with a 15% lower odds of LTSA during follow-up (OR 0.85, 95% CI 0.80- 0.90) after adjustment for age, sex, and employee and workunit level factors (table 2). Similar associations were observed for work-unit LQ in the medium (OR 0.84, 95% CI 0.76-0.94) and high (OR 0.73, 95% CI 0.65-0.82) tertiles in comparison with the low tertile (Ptrend<0.0001). The protective associations between work-unit LQ and LTSA in the linear and categorical models were mildly attenuated after either additional adjustment for prior LTSA or restriction to employees without prior LTSA, but remained statistically significant (table 2).

Interaction between chronic disorders and work-unit leadership quality

Given the considerably higher prevalence of prior LTSA among employees with somatic and/or mental disorders in comparison with healthy employees, we evaluated the associations between joint categories of major chronic disorders and work-unit LQ tertiles on LTSA during follow-up, and the association between work-unit LQ tertiles and LTSA during follow-up within strata of chronic disorders, among employees without prior LTSA (table 3). Lastly, we combined subgroups of only mental disorders and both somatic/mental disorders due to the small number of cases in both groups across strata of work-unit LQ tertiles. Findings from the joint-category models indicate that employees with only somatic disorders and low tertile LQ (ie, doubly adverse exposed) had a 2.37-times higher odds of LTSA (95% CI 1.93-2.90) than the non-exposed employees (ie, healthy and high tertile LQ). The effect size of this joint exposure was higher than expected from the sum of their individual main effects (RERI >0), indicating a supra-additive interaction, but that was not statistically significant as the CI overlapped the null value of 0 (RERI: 0.31, 95% CI -0.14-0.76). Employees with mental disorders and low tertile LQ had a 3.31-times higher odds of LTSA (95% CI 2.50-3.40), but the effect size of the joint exposure category was less than expected from the sum of their individual main effects (RERI <0), indicating a sub-additive interaction, but that was not statistically significant (RERI: -0.48, 95% CI -1.67-0.704).

The association between work-unit LQ tertiles and LTSA within strata of chronic disorder subgroups illustrates that the associations for low tertile exposure were very similar between the healthy and only somatic disorders (table 3); the association for the medium tertile was slightly weaker in magnitude in the only somatic disorder subgroup and did not reach statistical significance. In contrast, associations approximating close to null were identified for employees with any mental disorders. Pairwise multiplicative interactions between chronic disorder types and work-unit LQ tertiles were not statistically significant.

Population attributable fraction for work-unit leadership quality

Given that we did not observe a statistically significant interaction between chronic disorder and work-unit LQ on either the multiplicative or additive scale, we calculated the PAF for the pooled sample based on the multiple adjusted model where high tertile work-unit LQ is the reference category. The PAF associated with being in low and medium tertiles of unit-level LQ was 15.0%. This means that approximately 297 of the total number of LTSA cases in 1 year (1978) could be prevented if LQ in all work units is raised to the level that is observed in the high tertile, under the assumption that the association between LQ and LTSA is causal.

Sensitivity analyses

After stratification by job classification, the OR estimates for the medium and high tertiles varied across job classifications, but the CI across job classifications widely overlapped (supplementary table S5); with exception of the specific interaction between high tertile work-unit LQ and education and service/information technology related staff (low tertile work-unit LQ and nurses and nurse assistants as corresponding reference categories), no pairwise interaction terms met statistical significance (P>0.05). The associations between work-unit leadership tertiles and LTSA were robust to additional adjustment for household income and marital status (supplementary table S6), and similarly robust to inverse probability weights for exclusion from the study sample due to missing LTSA status or work-unit-level LQ (supplementary table S7).

Discussion

The findings from this longitudinal analysis of Danish public hospital employees, which consists of several occupational groups, indicate that higher LQ at the work-unit level was associated with lower risk of individual-level LTSA over a 1-year follow-up period. Assuming this association is causal, approximately 15% of all LTSA cases within one year could be prevented should LQ in work-units be raised to the highest level. While the association between work-unit LQ tertiles and LTSA was similar between healthy employees and employees with only somatic disorders, no association was observed in the small subgroup of employees with mental disorders, who already experienced a high level of LTSA irrespectively of LQ. That said, neither somatic nor mental disorders statistically significantly modified the association between work-unit LQ and LTSA.

While our measure of LQ deviated from the COPSOQ-II's quality of leadership scale used in many of the previous studies on this topic, the protective association observed for higher work-unit LQ in relation to LTSA is still consistent with several previous studies (11-15, 32, 33). We add new evidence to this finding by demonstrating that the association between LQ and risk of LTSA was similar among both healthy employees and employees with only somatic disorders, whereas the association was absent among employees with mental disorders. There is also limited evidence that is not entirely consistent with the premise that LQ is protective against LTSA. Investigators of the Danish general population 2004-2005 survey-based COPSOQ II study reported a slightly protective but not statistically significant association between LQ and 1-year LTSA (34). Findings from an earlier analysis of the 2000 Danish Work Environment Cohort Study (DWECS) indicate that the stronger protective effect of LQ on 1.5-year LTSA was limited to female workers (35). However a subsequent study, which pooled the COPSOQ II and 2000 DWECS surveys with several other Danish surveys into a large sample of 39 408 workers, found that lower LQ was associated with higher risk of 1.5 year-LTSA (13). Many of the previous studies on LQ and LTSA assessed LQ and LTSA at the individual-level, which may be limited by reporting bias. In a smaller sample (N=1734) of Danish workers in the human services sector, low-level work-unit LQ was associated with 75% higher risk of 1.5-year LTSA (rate ratio: 1.75, 95% CI 1.13-2.38) (15).

We hypothesized that higher work-unit LQ would be more protective against LTSA for employees with pre-existing chronic somatic and mental disorders, so it is notable that the relative association between LQ and LTSA were similar between healthy employees and employees with only somatic disorders, and that no clear association was observed for mental disorders. This indicates that LQ is an important psychosocial work resource both for workers with and without chronic disorders. The lack of association among employees with mental disorders is more puzzling and contrasts with findings from a pooled analysis of the 2000 and 2005 DWECS samples, which showed that higher LQ was more beneficial towards 2-year LTSA for workers with moderate depressive symptoms than for workers with no depressive symptoms (36). A possible explanation is that higher severity of illness and the high rate of LTSA already experienced among employees with mental disorders may make LQ less relevant as an important psychosocial work resource. Also, we focused on severe mental disorders which have led to medication use and/or hospital admission, and it is likely that higher work-unit LQ will be more beneficial or protective against LTSA for workers with early symptoms of mental disorders in comparison with workers with fully developed and clinically diagnosed disorders. The role of selection bias is another possibility through selection of workers with chronic mental disorders out of the study population. In a post-hoc analysis of workers employed during the 2011 wave of WHALE, we observed that workers with chronic mental disorders were less likely to be included in the current study (ie 2014 WHALE), independent of age, sex, and job classification (data not shown). Thus, those who remain employed at the hospital may be more resilient and therefore less responsive to work-unit LQ. Moreover, it is possible that for individuals with mental disorders, who in general have a high risk of LTSA, high work-unit LQ alone might not be sufficient to make a difference with regard to LTSA. Future studies should look into the effects of LQ on retention among people with and without mental disorders to address this issue.

Strengths and limitations

This study has numerous strengths including a large sample size with a high participation rate, inclusion of a wide range of occupational groups, register-based assessment of chronic disorders, determination of work-units and LTSA from detailed employer records, and the control for of wide array of potential confounders at the employee and work-unit level. By assessing LQ at the work-unit level, we are reducing reporting bias that could be influenced by pre-existing chronic disorders. Similarly, by linking information between chronic dis-orders (the Danish registers), LQ (questionnaire), and LTSA (employer records) from different data sources, we eliminated common method bias. There are also limitations to be considered. Baseline measurement of work-unit LQ may not have accurately reflected work-unit exposure over the follow-up period. This analysis only addressed LTSA and did not include SA shorter in length. Also, we did not have sufficient information on employees who changed work-units during follow-up. Should the change in work-unit result in change in LQ level, there is potential for exposure misclassification. However, we speculate any potential misclassification is independent of LTSA during followup and that bias would likely attenuate the association toward the null. There is also potential for selection bias in the form of missing data selection bias. However, the results from the sensitivity analysis that includes inverse probability weights suggests that the likelihood of this bias is minimal.

The current study also points towards future research directions that were not within the scope of this study. First, the current study did not examine SA episodes of shorter duration. An earlier longitudinal study of Danish workers reported protective associations between individual-level supervisor support and SA spells of 1-10 days and >10 days for men but not women (37). Whether higher work-unit LQ is more protective against SA spells of shorter length for workers with chronic disorders merits further investigation. Similarly, future research that examines which specific elements of LQ at the work-unit level are of most beneficial influence for workers with chronic disorders may help to inform preventive strategies by occupational healthcare professionals.

Concluding remarks

In this large sample of Danish public hospital employees, we observed that higher work-unit LQ was associated with lower risk of 1-year LTSA for the large majority of employees including those with chronic somatic disorders. This suggests that LQ is an important work resource for most workers independent of health status. LQ appeared less important for a smaller proportion of employees who suffer from mental disorders, possibly because they already show high rates of LTSA. Future studies should investigate the role of psychosocial resources for increasing labor market participation for workers with and without chronic somatic and mental disorders.

Sidebar

Mehta AJ, Mathisen J, Nguyen T-L, Rugulies R, Hulvej Rod N. Chronic disorders, work-unit leadership quality and longterm sickness absence among 33 025 public hospital employees. Scand J Work Environ Health. 2022;48(7):560-568.

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DETAILS

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Predicting long-term sickness absence among retail workers after four days of sick-listing

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ABSTRACT (ENGLISH)

Objective This study tested and validated an existing tool for its ability to predict the risk of long-term (ie, >6 weeks) sickness absence (LTSA) after four days of sick-listing. Methods A 9-item tool is completed online on the fourth day of sick-listing. The tool was tested in a sample (N=13 597) of food retail workers who reported sick between March and May 2017. It was validated in a new sample (N=104 698) of workers (83% retail) who reported sick between January 2020 and April 2021. LTSA risk predictions were calibrated with the Hosmer-Lemeshow (H-L) test; non-significant H-L P-values indicated adequate calibration. Discrimination between workers with and without LTSA was investigated with the area (AUC) under the receiver operating characteristic (ROC) curve. Results The data of 2203 (16%) workers in the test sample and 14 226 (13%) workers in the validation sample was available for analysis. In the test sample, the tool together with age and sex predicted LTSA (H-L test P=0.59) and discriminated between workers with and without LTSA [AUC 0.85, 95% confidence interval (CI) 0.83-0.87]. In the validation sample, LTSA risk predictions were adequate (H-L test P=0.13) and discrimination was excellent (AUC 0.91, 95% CI 0.90-0.92). The ROC curve had an optimal cut-off at a predicted 36% LTSA risk, with sensitivity 0.85 and specificity 0.83. Conclusion The existing 9-item tool can be used to invite sick-listed retail workers with a ≥36% LTSA risk for expedited consultations. Further studies are needed to determine LTSA cut-off risks for other economic sectors.

FULL TEXT

Headnote

Roelen CAM, Speklé EM, Lissenberg-Witte BI, Heymans MW, van Rhenen W, Schaafsma FG. Predicting long-term sickness absence among retail workers after four days of sick-listing. Scand J Work Environ Health. 48(7):579-586. doi:10.5271/ sjweh.4041

Objective This study tested and validated an existing tool for its ability to predict the risk of long-term (ie, >6 weeks) sickness absence (LTSA) after four days of sick-listing.

Methods A 9-item tool is completed online on the fourth day of sick-listing. The tool was tested in a sample (N=13 597) of food retail workers who reported sick between March and May 2017. It was validated in a new sample (N=104 698) of workers (83% retail) who reported sick between January 2020 and April 2021. LTSA risk predictions were calibrated with the Hosmer-Lemeshow (H-L) test; non-significant H-L P-values indicated adequate calibration. Discrimination between workers with and without LTSA was investigated with the area (AUC) under the receiver

operating characteristic (ROC) curve.
Results The data of 2203 (16%) workers in the test sample and 14 226 (13%) workers in the validation sample was available for analysis. In the test sample, the tool together with age and sex predicted LTSA (H-L test P=0.59) and discriminated between workers with and without LTSA [AUC 0.85, 95% confidence interval (CI) 0.83-0.87]. In the validation sample, LTSA risk predictions were adequate (H-L test P=0.13) and discrimination was excellent (AUC 0.91, 95% CI 0.90-0.92). The ROC curve had an optimal cut-off at a predicted 36% LTSA risk, with sensitivity 0.85 and specificity 0.83.
Conclusion The existing 9-item tool can be used to invite sick-listed retail workers with a ≥36% LTSA risk for expedited consultations. Further studies are needed to determine LTSA cut-off risks for other economic sectors.
Key terms external validation; occupational health service; prediction model; risk assessment; ROC analysis; sick leave.
Long-term sickness absence (LTSA) is a major problem with high societal costs in Organization for Economic Cooperation and Development (OECD) countries (1). LTSA is associated with financial and psychological problems among workers and may lead to future unemployment and societal exclusion (2). The LTSA risk increases with sickness absence duration and, therefore, workers at risk of LTSA are preferably identified before they report sick. However, prediction models for future LTSA in non-sick-listed workers show poor-to-moderate results (3-6), probably because of the low LTSA prevalence in the general working population. The performance is not sufficient to identify and target workers at risk of LTSA for preventive actions (7).
LTSA is more prevalent and may be better predicted among workers who report sick. Recently, Louwerse et al (8) developed an LTSA prediction model for sicklisted individuals without an employment contract. In The Netherlands, unemployed individuals report sick to UWV, the Dutch social security agency. A prediction model including educational level, expected sickness absence duration and problems (yes/no) with seeking help, distinguished between individuals with and without sickness absence one year later. The area under the curve (AUC) was 0.76 which indicates that in all random pairs of individuals, the prediction model correctly identified the one at highest LTSA risk in 76% of the cases. The authors concluded that the prediction model can be used to identify unemployed individuals with an increased risk of LTSA after reporting sick.
A prediction model for unemployed individuals, however, may not apply to employed workers. Dutch workers with an employment contract report sick to their employer, who asks an occupational health service (OHS) to advise about work accommodations and return-to-work (RTW) activities. For this purpose, sicklisted workers are usually invited to an OHS consultation in the fourth or fifth week of sickness absence. Arbo Unie is an OHS that provides occupational healthcare to 1.2 million workers employed in companies of different economic sectors throughout The Netherlands. Arbo Unie sends a brief (9-item) online tool to sick-listed workers four days after reporting sick to collect information about symptoms and reasons for sickness absence.
The objective of the present study was to test and validate the existing 9-item online tool for its ability to identify workers with an increased LTSA risk after four days of sick-listing.
Methods
Study context and design
In The Netherlands, employers financially compensate sickness absence for a maximum period of two years. Workers report sick to their employer, who records the first day of sickness absence into an OHS sickness absence register. Sickness absence dates are not registered real time, usually there is a delay of one or more days if employers do not register sickness absence in the OHS database on a daily basis.
The present study analyzed data which were collected within the context of usual occupational healthcare practice. The online tool has been in use for several years in the retail sector. A convenience sample (N=13 597) of food retail workers who reported sick between March and May 2017 was used to test the online tool for its LTSA risk predictions. LTSA risk predictions were validated in a sample of 104 698 workers who reported sick between January 2020 and April 2021. They were employed in retail (83%), transport (6%), healthcare (3%), industry (2%) and various other economic sectors (6%). The medical ethics committee of the Amsterdam University Medical

Centers granted ethical clearance for the study.

Predictor variables

The 9-item tool is completed online by the sick-listed worker on the fourth day of sickness absence.

The tool asked the worker about expectations of sickness absence duration (<1 week=1, 1-2 weeks=2, 2-5 weeks=3, >5 weeks=4), contact with the supervisor (no=0, yes but no RTW arrangements made=1, and yes and RTW arrangements made=2), sickness absence in the past 12 months (no=0, yes once=1, yes more than once=2), fatigue in the past 4 weeks (5-point frequency scale ranging from never=0 to always=4), pain in the past 4 weeks (5-point frequency scale ranging from never=0 to always=4), physical work demands (5-point frequency scale ranging from not at all=1 to very high=5), mental work demands (5-point frequency scale ranging from not at all=1 to very high=5), opportunities to accommodate work (no=0, yes=1), and whether or not a medical doctor (general practitioner or clinician) was visited (no=0, yes=1 but no treatment; and yes, receive treatment=2).

Age and sex were retrieved from the OHS sickness absence register and used as additional predictor variables.

Outcome variable

The day of reporting sick and the day of full RTW were retrieved at the individual level from the OHS sickness absence register. The duration of sickness absence was used to determine the outcome variable. Dutch sickness absence policies require the employer to contact the OHS if sickness absence is expected to exceed a duration of 6 weeks. In line with these policies, LTSA was defined in this study as sickness absence >6 weeks. Thus LTSA=0 for sickness absence durations <6 weeks and LTSA=1 for durations >6 weeks.

Statistical analysis

All statistical analyses were conducted in SPSS Statistics for Windows, version 26.0 (IBM Corporation, Armonk, NY, USA). The online tool could only be returned when all items were completed. Consequently, there were no missing responses on the tool's items.

In the test sample, age, sex and the 9 items of the online tool were included as independent variables in a multivariable logistic regression model with LTSA as outcome variable. The constant and regression coefficients of this multivariable logistic regression model were used to compute a linear predictor (LP) variable in the validation sample. LP was used as a single independent variable in logistic regression analysis of LTSA in the validation sample (9).

Calibration (ie, the accuracy of LTSA predictions) was investigated in both (test and validation) samples with calibration curves and the Hosmer-Lemeshow (H-L) goodness-of-fit test. A non-significant H-L P-value reflects that the predicted risks did not deviate significantly from the observed frequencies, indicating that calibration is adequate (9). Discrimination (ie, the ability to distinguish between workers with and without LTSA) was investigated in both samples with receiver operating characteristic (ROC) analysis, regarding the area under the ROC curve (AUC) as measure for discrimination (9). Perkins &Schisterman (10) stated that the "optimal" cut-off point in ROC analyses is the point which classifies most of the individuals correctly. The 'index of union' method proposed by Unal (11) was used to determine the optimal cut-off point.

We conducted a subgroup analysis investigating calibration and discrimination in the 17% non-retail workers of the validation sample to get an idea about the tool's performance in economic sectors other than retail.

Results

In the test sample, 9930 (73%) workers did not return the online tool; the OHS sickness absence register showed that most of them had resumed work within days and maximum one week of reporting sick. Of the 3667 workers who returned the tool, 1464 workers reported that they had already resumed work and were therefore excluded from the analyses. The data of the 2203 (16%) workers who were still sick-listed four days after reporting sick was used for testing LTSA risk predictions and discrimination by the 9-item online tool (figure 1). In the validation sample, 83 101 (79%) workers did not return the online tool. Of the 21 573 workers who returned the tool, 7347 reported they had resumed work. The data of 14 226 (13%) workers who were still sick-listed four days after reporting sick was used for validating LTSA risk predictions and discrimination by the existing 9-item online tool (figure 1).

Table 1 shows the study population characteristics and the online tool scores in the test and validation samples. In the validation sample, fewer workers expected to be absent for >5 weeks and more workers had had contact with their supervisor. Fatigue, physical work demands, and mental work demands were lower in the validation compared to the test sample.

Testing LTSA risk predictions and discrimination (N=2203)

In the test sample, 875 (40%) workers had LTSA. In multivariable analysis, the worker-reported expectation of sickness absence duration had the highest Wald statistic, indicating that it explains the highest part of the variance in LTSA (table 2). Older age, contact with supervisor without RTW arrangements, pain, mentally demanding work, and medical treatment were associated with a significantly higher LTSA risk. Sex, fatigue, prior sickness absence, physically demanding work, and opportunities to accommodate work were not significantly associated with the risk of LTSA.

The H-L test (model x2=6.53; df=8; P=0.59) reflected adequate calibration (figure 2). Discrimination between retail workers with and without LTSA was good, with an AUC 0.85 [95% confidence interval (CI) 0.83-0.87]. If the worker-reported expectation of sickness absence duration was eliminated from the model, the AUC decreased to 0.75 (95% CI 0.73-0.77). If contact with the supervisor was eliminated from the model, the AUC remained 0.85 (95% CI 0.83-0.86). The interaction terms 'age·physically demanding work', 'age·mentally demanding work', 'sex·physically demanding work' and 'sex·mentally demanding work' did not improve discrimination [data not shown].

Validating LTSA risk predictions and discrimination (N=14 226)

In the validation sample, 2156 (15%) workers had LTSA. The median predicted LTSA risk was 7.0% (interquartile range 1.6-31.6%). The H-L test was not significant (model x2=12.41; df=8; P=0.13), ie, the calibration of LTSA risk predictions was adequate (figure 2). Discrimination was excellent with AUC 0.91 (95% CI 0.90-0.92). The 'index of union' method showed that the optimal cut-off point was at a 36% LTSA risk, with sensitivity 0.85 and specificity 0.83.

In the subgroup of 4092 (17%) non-retail workers, there were 1130 LTSA events. The H-L test was x2=8.42 (P=0.39) and the AUC was 0.89 (95% CI 0.88-0.91). The optimal cut-off point was at a 29% LTSA risk, with sensitivity 0.84 and specificity 0.79.

Discussion

The existing 9-item online tool together with age and sex predicted the risk of LTSA after four days of sicklisting and discriminated well between sick-listed retail workers with and without LTSA. In a validation sample, LTSA risk predictions by the tool were adequate and discrimination was excellent.

The results of this study confirmed that workerreported expectation of sickness absence duration is a strong LTSA predictor (8, 12, 13). If the workerreported expectation of sickness absence duration was eliminated from the analysis, discrimination diminished from excellent to moderate. Thus, we need this variable to identify workers with an increased LTSA risk. Contact with supervisor was a second strong predictor variable that was positively related to LTSA when no RTW arrangements were made, and negatively though not significantly when there were RTW arrangements. Previously, Buys et al (14) reported that supervisor contacts facilitate RTW if sick-listed workers perceive the contacts as supportive. The lower LTSA risk found in the present study may be explained by supportive arrangements, for example, work accommodation strategies to make RTW easier. Supervisor contacts without RTW arrangements were associated with a significantly higher LTSA risk. It is well conceivable that agreeing on RTW arrangements is difficult if supervisors and workers have no idea about when RTW will be possible. If supervisor contact was eliminated from the analyses, discrimination did not change, indicating that the predictor variable was not essential for discriminating between retail workers with and without LTSA.

The other predictor variables may also be not essential for identifying workers at risk of LTSA four days after sick-listing. Nevertheless, we decided against removing predictor variables from the tool because the objective of the study was to test the tool as it is used now in occupational healthcare practice, not to develop a parsimonious LTSA risk prediction model. In line with the systematic review by Dekkers-Sanchez et al (15), age but not sex was associated with LTSA. Prior sickness absence was associated with a higher risk of LTSA in univariable analysis [data not shown], but lost significance in the multivariable model. The same holds for fatigue and physically demanding work. Mentally demanding work and pain were significantly associated with a higher LTSA risk. Higher LTSA risks were also found for medical doctor visits. A recent systematic review and meta-analysis of the literature showed that workers on paid sick leave have higher odds of seeing a doctor (16). Workers who receive treatment or are referred for clinical diagnostics and treatment are likely to have more severe disorders and thus a higher LTSA risk than those who don't need any treatment.

In prediction research, the overall performance of the multivariable model is more important than the association of individual predictor variables with the outcome (9). Calibration and discrimination are the most commonly used model performance indicators. Previous studies have investigated LTSA risk predictions in the healthy working population. Prediction models for risk of LTSA among non-sick-listed workers show adequate calibration but poor-to-moderate discrimination with AUCs varying between 0.68 (4) and 0.76 (6). Among sick-listed unemployed workers, Louwerse et al (8) reported discrimination by a three-predictor (educational level, expected sickness absence duration, and help-seeking ability) model, with an over-optimism adjusted AUC of 0.76. The present study confirms that workers with an increased risk of LTSA can be identified early after sick-listing. Instead of adjusting for over-optimism, we evaluated LTSA risk predictions in a new validation sample. Although not as good as in the test sample, the tool's predictions were still adequate in the validation sample. Discrimination between workers with and without LTSA in the validation sample was better than in the test sample.

Limitations of the study

The study had a two-sample design. The test sample (N=13 597) was a convenience sample of workers in food retail who reported sick between March and May 2017. The validation sample (N=104 698) included workers (83% retail) who reported sick between January 2020 and April 2021. Consequently, the tool's validation was temporal (ie, testing the validity of the tool over time) rather than external (ie, testing the tool in a different working population). Subgroup analysis showed that the tool also discriminated between non-retail workers with and without LTSA, though the LTSA cut-off risk was lower than in retail workers. This indicates that the tool could work in other economic sectors, but further validation studies are needed to determine LTSA cutoff risks for inviting workers to expedited consultations with occupational healthcare providers.

The response rate was low, 27% and 21% in the test and validation samples, respectively. Consequently, there is a drastic selection process in terms of who is left for testing and validating the tool. Sickness absence register analyses showed that most non-responders in the test sample had already resumed work. There was a 40% LTSA prevalence in the test sample as compared with a 10.7% LTSA prevalence in the Dutch workforce in 2018 (17). If workers with LTSA are overrepresented, the regression coefficients used for the LP variable might overestimate the LTSA risk in new populations with lower LTSA prevalences. Indeed, we found overestimations of the LTSA risk in the validation sample with a 15% LTSA prevalence, but overall the predicted LTSA risks did not deviate significantly from the observed LTSA frequencies. Further research is needed to investigate if LTSA risks are adequately predicted in more heterogeneous samples with workers employed in more diverse economic sectors. Compared to calibration, discrimination between sick-listed workers with and without LTSA will be less affected by non-response bias. ROC curves are independent of the prevalence of the outcome, because the curves are based on sensitivity (true-positive rates among those with the outcome) and specificity (true-negative rates among those without the outcome).

In contrast to the test sample, we had no knowledge about the workers in the validation sample who did not complete the online tool. In line with the test sample, it is likely that most workers in the validation sample did not respond because they had already resumed work or were thinking about resuming work. Alternatively, individuals with severe disease may want to focus on recovery rather than work. Some, particularly older individuals might have difficulties completing an online tool because they don't have a computer or internet. On the one hand, low response rates implicate a high risk of selection bias, which restricts the reproducibility and generalizability of the results. On the other hand, response rates were low in both samples and might be inherent to occupational healthcare practice. Response rates in primary and occupational healthcare are known to be low and declining (18, 19). By testing and validating the tool in the selective group of responders, we have insight in the tool's predictive performance in occupational healthcare practice as it is now. Response rates could be improved, for example by other ways of data collection such as telephone interviews. In that case, however, structural changes are needed in the organization of OHS healthcare services.

Practical implications

A 9-item online tool predicted the risk of LTSA among sick-listed workers after four days of sick-listing. In the present study, we found an optimal cut-off (ie, minimum misclassification) at a 36% and 29% LTSA risk among retail and non-retail workers, respectively. Sick-listed workers with a predicted LTSA risk above the cut-off should be invited to expedited OHS consultations to further explore the reasons for sickness absence and RTW barriers. A recent systematic review showed promising results for interventions addressing barriers and RTW facilitators (20). Occupational healthcare providers could play an important role in a participatory approach involving the sick-listed worker and the supervisor to solve RTW barriers early after sick-listing, thus expediting RTW and potentially preventing LTSA (21).

At a 36% LTSA risk, sensitivity was 0.85 for retail workers, which means that 15% of those with LTSA were missed for expedited consultations. They were invited for an OHS consultation as usual in the fourth or fifth week of sickness absence. If it is important not to miss workers at high risk of LTSA, then occupational healthcare providers could choose a lower LTSA risk with higher sensitivity as cut-off point. They should bear in mind, however, that the number of false positives increases with lower LTSA risk cut-off points. Consequently, more workers are invited for consultations, while they will not develop LTSA. This might result in medicalization of transient symptoms and unnecessary utilization of OHS healthcare services. Therefore, we recommend to carefully consider the pros and cons of LTSA cut-off risks for practical purposes.

Sidebar

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Association between rotating night shift work and carotid intima-media thickness among Chinese

steelworkers: a cross-sectional survey

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ABSTRACT (ENGLISH)

Objective This study aimed to examine the association between rotating night shift work and subclinical atherosclerosis among Chinese steelworkers. Methods We evaluated 3582 steelworkers who participated in the legally required health examination in 2017. Carotid intima-media thickness (CIMT) was measured using ultrasonography. Different exposure metrics of night shifts collected by face-to-face personal interviews were used to examine the relationship between night shift work and the mean CIMT. Results The mean CIMT values were 0.66 (standard deviation 0.22) mm in the study population. Current shift workers shown higher mean CIMT compared to day workers. There were no significant associations between the current shift status, the duration of night shifts, the cumulative number of night shifts, the average frequency of night shifts, and the mean CIMT after all confounding factors adjusted both in male and female. Conclusions Rotating night shift work is not associated with subclinical atherosclerosis among steelworkers. Further large-scale prospective longitudinal studies are warranted to confirm our findings.

FULL TEXT

Headnote

Objective This study aimed to examine the association between rotating night shift work and subclinical atherosclerosis among Chinese steelworkers.
Methods We evaluated 3582 steelworkers who participated in the legally required health examination in 2017. Carotid intima-media thickness (CIMT) was measured using ultrasonography. Different exposure metrics of night shifts collected by face-to-face personal interviews were used to examine the relationship between night shift work and the mean CIMT.
Results The mean CIMT values were 0.66 (standard deviation 0.22) mm in the study population. Current shift workers shown higher mean CIMT compared to day workers. There were no significant associations between the current shift status, the duration of night shifts, the cumulative number of night shifts, the average frequency of night shifts, and the mean CIMT after all confounding factors adjusted both in male and female.
Conclusions Rotating night shift work is not associated with subclinical atherosclerosis among steelworkers. Further large-scale prospective longitudinal studies are warranted to confirm our findings.
Key terms atherosclerosis; cardiovascular disease; China; shift worker.

The timing of 24-hour operations is a major challenge in organizing shift work and one of the major causes of circadian stress (1). The prevalence of shift work was estimated to range roughly 15-20% across industrial countries (2). Shift work may cause the disruption of biological rhythms and perturbation of social and family life, which can negatively influence mental well-being and physiological health (3). Moreover, the International Agency for Research on Cancer (IARC) has classified night shift work as "probably carcinogenic to humans" (Group 2A) in 2019 (4). As it is impossible to avoid night shift work completely, a better understanding of the health effects of shift work will be of great significance for developing preventive strategies for workers.

Cardiovascular diseases (CVD) continue to be the leading cause of death and the largest contributor to premature mortality worldwide (5), causing 40% of deaths in the Chinese population (6). In particular, ischemic heart disease and cerebrovascular disease account for nearly 10 million and 5 million deaths, respectively, globally every year (5).

Some studies have shown the association between shift work and clinical cardiovascular outcomes such as peripheral arterial disease, cardiovascular mortality, coronary heart disease (7-11) and atherosclerosis-related vascular events such as myocardial infarction and stroke (12) in both humans and animals (13, 14). In fact, CVD develops over a long period of time, with physical changes beginning decades before the disease manifests itself. However, some of the health hazards of shift work may remain undetected when a disease condition is used as an endpoint, with subsequent difficulty concerning a possible healthy worker effect since workers who cannot tolerate night work may change to day work when the first symptoms of CVD occur (1, 15). Therefore, it is important to include surrogate parameters that describe early sub- clinical changes (15). Carotid intima-media thickness (CIMT) is a non-invasive measurement obtained by ultrasound. It is a reproducible tool to assess subclinical atherosclerosis (16) and has been shown to reliably predict future CVD events (17, 18) in many kinds of epidemiological studies. Disrupted or misaligned circadian rhythms promote multiple pathologies, including chronic inflammatory and metabolic diseases such as atherosclerosis (19). However, it has not been determined whether the chronic disruption of circadian rhythms due to night shift work is responsible for carotid atherosclerosis. Apart from that, although demands have been made to improve the quality of exposure assessment of night shift work (20), coarse categorizations are still commonly used to assign exposures in studies of night shift work and subclinical atherosclerosis. The coarse categorizations of night shift work ignore important information that may have an impact on health, such as shift duration and rotation frequency, which may produce measurement error and exposure misclassification within groups. Therefore, it is necessary to study the association between different exposure metrics of night shift work and CIMT examined in the subclinical stage by imaging techniques. Based on the foregoing, in the present study, different exposure metrics, including current shift status, duration of night shifts (years), cumulative number of night shifts (nights) and average frequency of night shifts (nights/month) were used to examine the effects of night shift work on CIMT.

Methods

Study design and population

This study was based on cross-sectional data from the occupational population, and was conducted among steelworkers at 11 steel production departments owned by the HBIS Groups Tangsteel Company in Tangshan City, Hebei Province in North China. All workers at this company underdo a legally required health examination each year. A total of 7661 participants who underwent the annual legally required occupational health examinations were recruited from February to June 2017. There were 4084 workers who volunteered and completed carotid ultrasound examinations. After excluding 205 workers with insufficient shift work data, and 297 workers without complete information on the main covariates of the questionnaire, a total of 3582 participants were included in the final analysis. All participants gave informed consent before taking part in this study. The Ethics Committee of North China University of Science and Technology approved the research in this study (No. 16040).

Measurement of carotid intima-media thickness

Two trained sonographers performed the assessment of CIMT from both the left and right carotid artery systemusing a high-resolution B-mode topographic ultrasound system using a 7.5 MHz frequency probe (PHILIPS, HD7, China). They were blinded to the research purpose and the study design. Participants were examined in the supine position with their heads rotated in the opposite direction of the probe and with a lateral probe orientation. Common carotid artery (CCA) IMT was measured over a distance of 10 mm proximal to the common carotid bulb on both the left and right sides, excluding focal plaques at the proximal edge, midpoint, or distal edge of the distal CCA in the far wall (21, 22). Three representative measurements were taken per side. Mean CIMT values were calculated from six independent measurements (three per side) (23). To assess intra-reader reproducibility, 5% random workers were re-read with the intra-class correlation coefficients of 0.92.

Assessment of night shift work

The main work schedule of the present study population was introduced in detail in our previous research (24, 25). In brief, shift work in this study refers to rotating night shifts (the current main four-crew-three-shift system and the historical three-crew-two-shift system). Detailed lifetime employment history was collected in this study by face-to-face personal interviews, and all the reported information was verified with the company s records. Recruited participants were asked to report whether they were involved in rotating night shift work (working 00:00-6:00 hours) during their employment (current shift status: day work, ever, current). If participants responded yes (ever or current), they were asked further about the start and end dates of each shift system, the average number of night shifts worked per month in each shift system. If participants responded no, they were defined as day workers. The duration of night shift work (sum of years spent in all different night shift systems), cumulative number of night shifts (sum of nights spent in all different night shift systems) and average frequency of night shifts (cumulative number of night shifts (nights) divided by cumulative number of months of employment) were derived by using the work schedule information described above.

Assessment of covariates

The covariates mainly included established risk factors for CVD (26): body mass index (BMI), smoking status, drinking status, diet [dietary approaches to stop hypertension (DASH)], physical activity, sleep duration, insomnia, hypertension, diabetes, dyslipidemia, the use of antihypertensive, antidiabetic and lipid-lowering drugs. Other sociodemographic information was also collected by the questionnaire: age, sex, marital status, educational level. Four mainly related occupational hazard factors including dust, heat stress, noise and carbon monoxide were measured by a qualified third-party company in accordance with the National Occupational Health Standards of the People's Republic of China (see the supplementary material)

Statistical analysis

Continuous variables are presented as the means and standard deviations (SD), and between-group comparisons were performed using Student's t-test or analysis of variance (ANOVA) of normally distributed data. Categorical variables are presented as numbers and percentages, and the chi-square test was used to compare differences among groups. Generalized linear models (GLM) were used to assess the association between different exposure metrics of night shift work (current shift status, duration of night shifts, cumulative number of night shifts, and average frequency of night shifts) and CIMT (continuous variable) using the Statistical Analysis System (SAS) procedure "PROC GENMOD". Associations between different exposure metrics of night shift work (in quartiles) and CIMT (in quartiles) were reported as odds ratios (OR) and the corresponding 95% confidence intervals (CI) from multiple adjusted logistic regressions. The risk factors and potential confounders were included in the analysis. We fit an unadjusted model and a fully adjusted model including age, sex, marital status, educational level, BMI, smoking status, drinking status, DASH score, physical activity, sleep duration, insomnia, hypertension, diabetes and dyslipidemia. Restricted cubic spline (RCS) models were utilized to visually examine the association between the duration of night shifts (continuous variable), cumulative number of night shifts (continuous variable) and CIMT (continuous variable) with adjustment for potential confounders. Two sensitivity analyses were performed to test the robustness of the results, including further adjustments for the four major occupational hazards and elimination of the last 1% quantile of the duration of night shifts and cumulative number of night shifts. A two-tailed $P<0.05$ was considered statistically significant. All statistical analyses were performed using SAS V9.4 (SAS Institute, Cary, NC, USA).

Results

General characteristics of the participants

Table 1 shows the basic characteristics of the participants according to the current shift status. The present study included a sample of 3582 participants, with 90.5% being male, a mean age of 46.0 years, and a mean BMI of 25.2 kg/m2. The prevalence of hypertension, diabetes and dyslipidemia in the study participants was 32.3%, 13.6%, and 40.1%, respectively. Current smoking, current drinking, and low physical activity were more likely to be reported among current shift workers. Compared with day workers, the sleep duration was relatively shorter among current shift workers. In terms of current health status, current shift workers also showed higher levels of CIMT, BMI, systolic blood pressure, diastolic blood pressure, total cholesterol and LDL-C. As shown in supplementary table S1, compared with female workers, male workers had higher CIMT and BMI levels, and higher proportions of smoking, drinking, hypertension, diabetes, and dyslipidemia. In addition, the CIMT showed age differences (supplementary table S2).

Association between duration of night shifts and CIMT

The CIMT values for the whole participants were 0.66 (SD 0.22) mm (table 1). The GLM analysis revealed positive and significant associations of different exposure metrics of night shift work with the CIMT in the unadjusted model (table 2). After further adjusting all other confounding factors (age, sex, marital status, educational level, BMI, smoking status, drinking status, DASH score, physical activity, sleep duration, insomnia, hypertension, diabetes and dyslipidemia), the current shift status, duration of night shifts, cumulative number of night shifts and average frequency of night shifts did not show significant associations with the CIMT (table 2).

Table 3 shows the results from the logistic regression model, which was performed to maximize the difference between the outcomes of exposure (Q4 versus Q1 quartile of the CIMT distribution). When the outcome was dichotomized as CIMT in the Q4/Q3/Q2 quartile versus Q1 quartile of the CIMT distribution, there were no significant associations between different exposure metrics of night shift work and the CIMT after all confounding factors adjusted (table 3). No significant associations were observed among male or female workers (supplementary table S4). Moreover, positive associations (without statistical significance) were observed between the duration of night shifts, cumulative number of night shifts and the CIMT in the RCS models (figure 1).

To avoid the influence of the maximum value on the fitting result of the RCS models, we removed the last 1% quantile of the duration of night shifts and cumulative number of night shifts, and the results remained stable (supplementary figure S1). Considering that dust, heat stress, noise, and carbon monoxide are the main occupational hazards for current steelworkers, we further adjusted these exposures on the basis of Model 3, as shown in table 3, and the results remained stable (supplementary table S4).

Discussion

In this cross-sectional study of occupational populations, we did not demonstrate an association between different exposure metrics of night shifts and the mean CIMT, a measure of subclinical atherosclerosis. The lack of association may be explained by several reasons. First, CIMT values may be obtained from measurements taken at different carotid segment points on one or both sides, which affected the comparability between different studies. Second, the presence of cardiovascular risk factors in this occupational population may account for the majority of the explained variance in the CIMT and, therefore, the addition of shift work may have a limited effect, which is difficult to detect because of the shared variance with traditional risk factors.

Our results are inconsistent with the association between rotating shift work and subclinical atherosclerosis. Previous studies have revealed that shift workers have significantly higher levels of inflammatory, cardiometabolic risk markers, cardio-ankle vascular index, arterial stiffness and CIMT than daytime workers in adjusted models (15, 22, 27, 28). Analyses of the baseline data of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) revealed the increase in exposure to night work was significantly associated with an increase in CIMT among men using a structural equation model (29). However, the lack of association observed in our study has also been reported in the Cardiovascular Risk in Young Finns study (CRYFS): Although shift work was associated with higher mean IMT (ß=0.029, P=0.021) and maximum IMT (ß=0.029, P=0.028) after adjusting for age only in men, CRYFS found no associations between shift work and mean IMT (ß=0.025, P=0.057) and maximum IMT (ß=0.026, P=0.057) after further adjusting for all potential risk factors (3). It is noteworthy that these studies often have a coarse assessment of shift work (usually divided into two or more categories, such as day workers and shift workers). However, simply exploring the relationship between coarse exposure indicators of shift work (eg, day versus night worker) and CIMT is not enough to reflect the carotid artery burden and to provide guideline recommendations regarding the risk related to shift schedules, since complete avoidance of rotating night shift work is difficult for socioeconomic realities. Low socioeconomic status is associated with higher blood pressure, and this association is particularly evident in the level of education (30). Education level might strongly influence adherence through knowledge of hypertension and health behavior, and highly educated people could often improve their working conditions, healthcare and income, which could decrease or delay the occurrence of hypertension (31). In our study, compared with night shift workers, day workers were more educated, received more antihypertensive drugs, smoked and drank less. Night shift workers may have less chance to visit doctors and receive appropriate medication. Regular medication keeps blood pressure in a relatively normal range, and we cannot exclude the influence of regular/irregular medication on blood pressure in the occupational health examination. This partly explains the results that systolic and diastolic blood pressure were significantly higher in night shift workers than day workers, while the prevalence of hypertension was not significantly different.

Several probable pathways are likely to underlie the association between shift work and subclinical atherosclerosis. One potential mechanism is the presence of psychological and psychosocial stressors (32). Shift workers are subjected to increased stress (such as job strain or community-wide events) than non-shift workers (33). One of the principal mechanisms translating chronic stress into adverse cardiometabolic outcomes is up-regulation of the hypothalamic pituitary adrenal (HPA) axis (34). Chronic elevation of the stress hormone cortisol enhances a set of phenotypic adaptations that promote an overall pro-inflammatory and proatherogenic milieu (34). Stress affects the cardiovascular system by stimulating the sympathetic nervous system, impairing endothelial function and creating a hypercoagulable state. All these changes have the potential to result in myocardial infarction or sudden death (35). In addition, shift work may increase the risk of atherosclerosis through adverse effects on sleep (36). Chronically disrupted circadian rhythms, through adipose tissue dysfunction and associated high-risk metabolic traits, create a milieu conducive to atherosclerotic cardiovascular disease (ASCVD) (37).

The major strengths of our study include detailed shift work information and lifestyle information, a large sample size, and accurate calculation of CIMT by ultrasonography. However, our research also has certain limitations. First, we were unable to infer the temporality of shift work and CIMT according to a cross-sectional study. Second, compared with workers who did not take carotid ultrasound, those who did were older, less male, and had higher SBP, DBP, and FBG levels (supplementary table S5). These workers may pay more attention to their physical state due to their age and poor health, introducing volunteer bias. Third, our survey participants were currently participating in the standard four-crew-three-shift system, and different shift systems were only found during the historical period, which made it impossible to directly compare the relationship between different types of night shift systems and the CIMT. Fourth, our study participants are all front-line workers from the production sector, so it was not possible to take into account the occupational category (office or physical workers) that could be confounder of atherosclerosis presence (38). Fifth, those who are competent for long-duration night shift work are more likely to have better physical fitness (the healthy worker effect) or have acclimated to night shift work, which may result in an underestimation of the association between exposure and outcome. Finally, this study was conducted in a steel production occupational setting, and the vast majority of steelworkers are male, which limits the results to the general population.

Concluding remarks

Different exposure metrics of night shift work were not associated with the CIMT. Further large-scale prospective longitudinal studies are warranted to confirm our findings.

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Sidebar

Wang L, Zhang S, Yu M, Wu J, Li X, Yuan J. Association between rotating night shift work and carotid intima-media thickness among Chinese steelworkers: a cross-sectional survey. Scand J Work Environ Health. 2022;48(7):511-519. doi:10.5271/ sjweh.4031

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Footnote

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Combined psychosocial work factors and risk of long-term sickness absence in the general working population: Prospective cohort with register follow-up among 69 371 workers

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ABSTRACT (ENGLISH)

Objective This study aimed to investigate the importance of combined psychosocial work factors for the risk of long-term sickness absence (LTSA). Methods We followed 69 371 employees in the general working population (Work Environment and Health in Denmark study 2012-2018), without LTSA during the preceding year, for up to two years in the Danish Register for Evaluation of Marginalization. Using k-means cluster analyses and weighted Cox-regression controlling for age, gender, survey year, education, health-behaviors, and physical work demands, we determined the prospective association of 11 identified clusters - based on the combination of nine psychosocial work factors (recognition, quantitative demands, work pace, emotional demands, influence, justice, role clarity, role conflicts, and support from colleagues) - with the risk of LTSA. Results During 124 045 person-years of follow-up, 6197 employees developed LTSA (weighted 8.5%). Using the cluster with the most favorable psychosocial scores as reference, clusters scoring poorly on several combined psychosocial factors had increased risk of LTSA. The cluster scoring poor on all nine psychosocial factors exhibited the highest risk [hazard ratio (HR) 1.68, 95% confidence interval (CI) 1.45-1.94]. Scoring poorly on one or two psychosocial factors did not increase the risk of LTSA when combined with favorable scores on the other psychosocial factors. Interaction analyses showed that gender, but not age and education, modified the association between cluster and LTSA. Conclusion Scoring poorly

on several combined psychosocial work factors plays an important role in the risk of LTSA. Scoring favorably on several psychosocial factors outweighed the potentially adverse effects of scoring poorly on one or two factors.

FULL TEXT

Headnote

Objective This study aimed to investigate the importance of combined psychosocial work factors for the risk of long-term sickness absence (LTSA).

Methods We followed 69 371 employees in the general working population (Work Environment and Health in Denmark study 2012-2018), without LTSA during the preceding year, for up to two years in the Danish Register for Evaluation of Marginalization. Using k-means cluster analyses and weighted Cox-regression controlling for age, gender, survey year, education, health-behaviors, and physical work demands, we determined the prospective association of 11 identified clusters - based on the combination of nine psychosocial work factors (recognition, quantitative demands, work pace, emotional demands, influence, justice, role clarity, role conflicts, and support from colleagues) - with the risk of LTSA.

Results During 124 045 person-years of follow-up, 6197 employees developed LTSA (weighted 8.5%). Using the cluster with the most favorable psychosocial scores as reference, clusters scoring poorly on several combined psychosocial factors had increased risk of LTSA. The cluster scoring poor on all nine psychosocial factors exhibited the highest risk [hazard ratio (HR) 1.68, 95% confidence interval (CI) 1.45-1.94]. Scoring poorly on one or two psychosocial factors did not increase the risk of LTSA when combined with favorable scores on the other psychosocial factors. Interaction analyses showed that gender, but not age and education, modified the association between cluster and LTSA.

Conclusion Scoring poorly on several combined psychosocial work factors plays an important role in the risk of LTSA. Scoring favorably on several psychosocial factors outweighed the potentially adverse effects of scoring poorly on one or two factors.

Key terms absenteeism; cluster analysis; occupational exposure; psychosocial.

In most countries, the employer is responsible for ensuring a healthy and safe work environment. During the past century, preventive efforts have mainly focused on 'classical problems' such as physical and chemical risk factors at the workplace. However, within the last decades, illness and absence from work due to mental health issues have led to increased focus on psychosocial factors within the work environment.

To this end, researchers have analyzed associations between the psychosocial work environment and health outcomes using different approaches. One approach is to define adverse psychosocial working conditions in accordance with theoretical models. The most frequently used - and best-evaluated - is the so-called "job strain model", which is based on the notion that high job demands combined with low job control increase risk of diseases and disorders (1). Another widely-used model is the one related to effort-reward imbalance (ERI). This is based on the notion that an imbalance between high efforts spent at work and low rewards received, in terms of salary, recognition from the management, job security and promotion process, is health-hazardous (2). Likewise, researchers have also used the model of organizational justice, theorizing that exposure to low justice at work increases the risk of poor health (3). Recently, these findings were summarized in a meta-review of 72 systematic reviews, which reported convincing evidence that exposure to job strain and ERI is prospectively associated with an increased risk of poor health (4), in particular cardiovascular disease (5, 6) and depressive disorders (7-9). Additionally, low organizational justice has also been associated with increased risk of poor health. However, compared to the literature on job strain and ERI, the evidence is based on fewer studies and is less robust (10, 11).

A second approach is to examine numerous individual psychosocial work environment factors, rather than relying on theoretical models (12, 13). Thus, several studies have investigated the influence of one psychosocial factor while controlling for others, or explored their possible interactions. Such an approach raises the question whether specific combinations of risk factors may lead to synergistic or antagonistic effects. This question is difficult to answer using traditional interaction analyses, as the number of possible combinations grow exponentially, thereby substantially

reducing statistical power.
A third, but rarely utilized, approach in work environment research is grouping individuals most alike in terms of the exposure variables in clusters in order to study the joint contribution of several psychosocial work factors. In the present paper, we utilize a clustering approach for examining possible joint associations between different combinations of psychosocial work factors and risk of poor health. Cluster analyses draw on hidden patterns in the data, and can - in the context of occupational research - identify clusters of workers with similar exposure characteristics. We have previously utilized this method to investigate the association between seven combined ergonomic work factors and risk of developing musculoskeletal pain (14).
In the present study, we used data from the Work Environment and Health in Denmark (WEHD) survey, which includes different psychosocial work environment variables. We included factors assumed to affect health outcomes via long-term stress processes, excluding factors such as workplace bullying or sexual harassment, as these presumably affect health and well-being more immediately. Likewise, we did not include factors at a higher hierarchical level, such as leadership quality, that may affect several of the other factors (15). Lastly, we excluded job insecurity, as it likely reflects the general economic- and labor-market situation more than the local work environment. Thus, we included the following nine factors: (i) quantitative demands (component of both job strain and ERI model, (ii) work pace (component of both job strain and ERI model), (iii) job control (component of the job strain model), (iv) recognition (component of ERI model), (v) justice at work (as a measure of organizational justice), (vi) emotional demands (a factor of increasing interest in epidemiological studies, in particular in Denmark (16), (vii) role clarity, (viii) role conflicts (two "classic" work environment factors, albeit with limited evidence from large-scale epidemiological cohort studies) (17) and (ix) collaboration and support from colleagues (representing a "classic" psychosocial work environment factor, which is also a part of the iso-strain model) (18) as well as a key component of the more recent approach of workplace social capital (19).
In the present analyses, we use long-term sickness absence (LTSA) as the outcome. LTSA, based on national registers, is strongly associated with measures of morbidity and mortality, and is therefore a reliable global indicator of poor health (20-22). LTSA constitutes a considerable burden for public finances in numerous countries, including Denmark, where municipalities reimburse employers for sickness absence benefits. We hypothesize that workers exposed to multiple risk factors exhibit a higher risk of LTSA compared to those exposed only to a few. However, as cluster analyses are inherently exploratory, we have no a priori assumption about which specific combinations most influentially increase the risk of LTSA. Against this background, the aim of this study is to investigate the importance of combined factors in the psychosocial work environment for the risk of LTSA. Furthermore, we explore whether age, gender and education modify the associations, as previous studies have suggested such effect modification (23-25).

Methods

Study design and population

This study combines all four waves (2012, 2014, 2016, and 2018) of the WEHD (26, 27) with the Danish Register for Evaluation of Marginalisation (DREAM). In each WEHD wave, probability samples of Danish residents aged 18-64 years, employed for a minimum of 35 hours per month with an income of at least 3000 DKK (approximately €400) per month in the past three months, were invited to participate. From 2012 to 2018, 228 173 people were invited, of which 127 882 (56%) responded to the survey. We included only people confirming through the survey that they were currently employed wage earners (N=110 357), ie, we did not include those self-employed. For people participating in more than one WEHD wave, we included only first occasion responses (N=73 298). Finally, we included only wage earners without LTSA during 52 weeks before their individual survey response and those replying to all questions about psychosocial work factors (N=69 371). Reporting is in accordance with the STROBE guidelines on cohort studies (28).

Psychosocial work factors (exposure)

The psychosocial work factors included in WEHD are primarily based on the Copenhagen Psychosocial Questionnaire (COPSOQ). We included the following nine psychosocial work factors (15, 29-31):

* PS1: - Recognition (REC) (1 item): How often is your work recognized and appreciated by management?
* PS2: Quantitative demands (QUD) (5 items, Cronbach's alpha 0.74): (i) How often do you have enough time for your work tasks? (Reversed in the normalized score.) (ii) How often do you experience deadlines that are difficult to keep? (iii) How often do you receive unexpected work tasks that put you under time pressure? (iv) How often are you available outside normal working hours? (v) How often do you have to work overtime?
* PS3. Work pace (WOP) (1 item): How often is it necessary to keep a high work pace?
* PS4. Emotional demands (EMD) (1 item): How often are you emotionally affected by your work?
* PS5. Job control (JCO), also called "influence at work" or "decision latitude" (2 items, Cronbach's alpha 0.75): (i) How often do you influence how you solve your work tasks? (ii) How often do you influence when you solve your work tasks?
* PS6. Justice (JUS) (2 items, Cronbach's alpha 0.73): (i) How often are all employees affected by a decision heard? (ii) How often are all the employees treated fair at the workplace?
* PS7. Role clarity (RCL) (3 items, Cronbach's alpha 0.77): (i) How often do you get the necessary information for doing your work? (ii) How often do you get the necessary help and instructions for doing your work? (iii) How often do you know exactly what your work task are?
* PS8. Role conflicts (RCO) (1 item): How often do you experience contradictory demands at work?
* PS9. Collaboration and support from colleagues (COL) (2 items, Cronbach's alpha 0.77): (i) How often do you and your colleagues help each other in achieving the best possible results? (ii) How often do you and your colleagues collaborate when facing problems that require a solution?

Participants responded on a 5-point Likert scale ranging from 'always' to 'never'. Responses were normalized on a scale ranging from 0100, where never=0 and always=100 (32), except for the first quantitative demands item, which was reversed. The nine normalized scales were used for the cluster analysis.

Long-term sickness absence (outcome)

We linked survey responses from the WEHD study to the DREAM register through a unique personal identification number from the Central Person Register that is provided to all Danish residents at birth and to foreigners when immigrating to Denmark (21, 22). In Denmark, the first 30 days of sickness absence are financially covered by the employer, after which the municipality can reimburse the remaining days. DREAM contains weekly - and not daily - information about reimbursement of sickness absence payments. Thus, >30 days of consecutive sickness absence corresponds to 6 consecutive weekly registrations in DREAM as the first week of sickness absence may begin on the last day of the week, and the last week of sickness absence may begin on the first day of the week (ie, 1 + 4 x 7 + 1 days = 30 days). Therefore, we defined LTSA as having registered sickness absence in DREAM for a period of >6 consecutive weeks for a period of up to 2 years, starting the week after replying to the survey (33). For the last WEHD wave (2018), the follow-up period is limited to about 1.5 years (until the end of 2019, ie, before the start of the COVID-19 pandemic).

Control variables

Age (continuous variable) and gender (man, woman) for each individual were drawn from the Central Person Register of Denmark. Year of survey reply was a categorical variable (2012, 2014, 2016, and 2018). Highest completed education was drawn from a national register and included as a categorical variable (less than higher education, higher education). Health-behaviors included smoking status (categorical variable: daily, once in a while, ex-smoker, never), body mass index (BMI, kg/ m2, continuous variable calculated from weight and height of the participants), leisure-time physical activity (continuous variable, total weekly hours of leisure physical activity). Physical workload (ergonomic index) was included as a continuous variable (33). Depressive symptoms [Major Depression Inventory (MDI), scale 0-50] was entered as a continuous variable (34). Frequency of musculoskeletal pain during the last three months was entered as a categorical variable (ie, daily, weekly, monthly, a few times, not at all). As health behaviors, depressive symptoms and frequency of musculoskeletal pain may also be potential mediators that could lead to over-adjustment, we present both minimallyand fully adjusted statistical models as well as sensitivity analyses.

Statistical analyses

Using k-means cluster analyses (Proc FastClus, SAS version 9.4, SAS Institute, Cary, NC, USA) of the nine psychosocial work factors, we identified naturally occurring clusters in the working population (14). Checking for multicollinearity (r >0.70) did not lead to exclusion of any of the nine psychosocial factors. To determine the optimal number of clusters, we repeated the FastClus procedure with up to 20 clusters and compared the cubic clustering criterion (CCC), pseudo F, and explained variance (R2) against the number of clusters. This showed local peaks in CCC values (indicating possible good clustering) at 11, 13, 15 and 18 clusters with CCC values of 115, 113, 112 and 113, respectively. The corresponding pseudo F values were 6614, 5977, 5472 and 4908, respectively. The corresponding R2 values were 0.49, 0.51, 0.52 and 0.55, respectively. As all of these clustering possibilities could potentially be used, we chose the option with fewest clusters (ie, 11 clusters) to avoid a range of small clusters for further analyses.

Using the survey version of the Cox proportional hazard model (35) (Proc SurveyPhreg of SAS version 9.4.) we calculated hazard ratios (HR) of LTSA during follow-up for the different clusters. We used a time-tofirst-event analysis and censored in case of one of the following criteria: Reaching the end of the two-year follow-up period, early retirement, disability pension, statutory retirement, emigration, or death, whichever came first. Each respondent was assigned a weight (based on information from national registers) to make the estimates representative. The weight variable repairs non-response and possible deviations of the probability sample from the population, and we did therefore not impute missing data.

We performed both minimally- and fully adjusted statistical models as well as sensitivity analyses. Model 1 (minimally adjusted) adjusted for age, gender, education, and year of survey reply. Model 2 (fully adjusted) additionally adjusted for health-behaviors and physical workload. Additionally, in three sensitivity analyses, we (i) controlled for musculoskeletal pain (pain frequency, categorical variable), (ii) controlled for mental health (MDI, continuous variable), and (iii) restricted the analyses to a subgroup of generally healthy individuals at baseline (excluding those with daily or weekly pain, or MDI scores >20). Finally, in the fully adjusted model 2, we tested for possible interactions of cluster with age, gender and education, respectively. In case of a statistical significant interaction (P<0.05), we provided additional stratified results. Results are reported as HR with 95% confidence intervals (CI).

Results

Table 1 shows baseline characteristics of the 69 371 participants in terms of age, gender, education, healthbehaviors, work characteristics, musculoskeletal pain and depressive symptoms. During 124 045 person-years of follow-up, 6197 employees developed LTSA (50 cases per 1000 person-years. The weighted percentage of LTSA during the follow-up period was 8.5%. Figure 1 shows the unadjusted weighted percentages of LTSA in each cluster, stratified by gender.

Table 2 shows the results for the 11 identified clusters. For each cluster, the weighted mean values of each of the nine psychosocial work factors (PS1-PS9) are presented and marked with color grades to ease interpretation. In other words, cluster 1 is characterized by favorable scores for all psychosocial factors. Cluster 2, 3, and 4, are characterized by poor scores for work pace, emotional demands, and recognition, respectively, but favorable scores for several of the other psychosocial factors. Cluster 5 is characterized by poor scores for role conflicts, emotional demands and moderate to poor for quantitative demands, but still having good scores for recognition, job control, justice, role clarity and support from colleagues. Cluster 6 is mixed with favorable scores for quantitative demands and work pace, while scoring moderate for the rest. None of these clusters (ie, cluster 2-6) showed increased risk of LTSA in any of the analyses, neither minimally nor fully adjusted or sensitivity analyses, compared with the reference group (cluster 1). Thus, scoring poorly on one or two psychosocial factors while having favorable scores on the other psychosocial factors was not associated with an increased risk of LTSA. However, individuals in clusters scoring poorly on several psychosocial factors had an increased risk of LTSA (cluster 7-11). Cluster 11, scoring poorly on all nine psychosocial factors, showed the highest risk (HR 1.68, 95% CI 1.45-1.94) in the fully adjusted analysis. Interaction analyses showed that gender (F=1.91, P=0.039), but not age and education,

influenced the association between cluster and risk of LTSA. Consequently, we present gender-stratified analyses of model 2 in the last two columns of table 2.
Table 3 shows the sensitivity analyses. Controlling for frequency of pain reduced the risk estimates slightly, while controlling for depressive symptoms resulted in loss of statistical significance for the estimates of all clusters. However, based on visual inspection of the point estimates and their 95% CI, cluster 10 and 11 still appear to have an increased risk for LTSA compared with cluster 2, 3 and 4 (no overlap of CI). Including only generally healthy individuals at baseline also reduced the estimates, leaving only cluster 11 with a statistically significantly increased risk. Further, the analyses including generally healthy individuals at baseline showed that cluster 2 (scoring favorable on 8 of the 9 psychosocial work factors with the exception of work pace) had a lower risk compared to the reference group (scoring favorable on all 9 psychosocial work factors).
Table 4 shows the distribution of psychosocial work clusters for the different job groups in the study. Job group per se was not included as a variable in the statistical analyses but presented to put the results into context and examine whether the different clusters represented specific job groups. Overall, the clusters did not represent any particular job groups, ie, the different job groups included many different clusters, though some jobs had more high-risk clusters than others. Examples of job groups with relatively many individuals in highrisk clusters were police officers and prison guards, mail carriers, medical doctors, vocational education teachers, food and related products industrial laborers, social workers, and high school teachers. At the other end of the scale, examples of job groups with relatively few individuals in high-risk clusters were clinic and dental assistants, farmers and gardeners, building and cleaning supervisors, child daycare workers (note: taking care of children in the workers' own home), as well as hairdressers and beauticians.

Discussion

In the present study, we used k-means cluster analyses to identify clusters of workers with similar exposure characteristics. The analysis identified 11 different clusters corresponding to different combinations of psychosocial work exposures. Our study showed that scoring poorly on several psychosocial work factors plays an important role in the development of poor health, expressed herein as LTSA. Importantly, scoring favorable on several psychosocial factors outweighed the potentially adverse effects of scoring poorly on one or two factors.
Karasek's job-strain model is probably the most thoroughly tested and documented model in the field of psychosocial work environment research (5-8, 36, 37). The job-strain model states that a combination of high demands and low control has detrimental effects on employees' health. In the present study, cluster 11 corresponds to high demands and low control and confirms the adverse effect of this combination on employees' health. However, this cluster was also characterized by poor scores on all the other psychosocial work factors. None of the clusters came out with the combination of high demands and low control while simultaneously scoring favorable, or even moderate, on other psychosocial work factors. Thus, the strong and consistent association between high job-strain and poor health reported in the literature may partly be due to co-occurrence with several other adverse psychosocial work factors.
Siegrist's ERI model is another well-known framework, proposing that a certain combination of psychosocial work exposures increases the risk of poor health (6, 9, 36). In cluster 4 and 10, poor scores on recognition - which can be considered as a type of low reward - were combined with favorable scores on quantitative demands and work pace (effort). This combination should, according to Siegrist's model, not increase the risk of adverse health outcomes. While this was true for cluster 4, we found increased risk of LTSA in cluster 10. The main difference between these two clusters is the co-occurrence of several adverse psychosocial exposures in cluster 10, ie, poor scores on job control, justice, role conflicts and support from colleagues. Hence, these negative factors appear to outweigh the potential benefit of low efforts.
Collectively, our results are broadly in line with these known theoretical models, ie, job-strain and ERI. However, our study also revealed the relevance of identifying naturally occurring clusters of psychosocial work exposures, as these represent common combinations of workplace exposures.
We assumed a priori that the cluster with the most favorable psychosocial work scores (cluster 1) should be defined

as the reference cluster - ie, cluster 1 had high scores for recognition, job control, justice, role clarity and collaboration combined with low scores for quantitative demands, work pace, emotional demands and role conflicts. Nevertheless, clusters 2, 3, 4, 5 and 6 did not - in any of the analyses - show increased risk of LTSA and may even suggest a J-shaped association. In the gender-stratified analysis (women) and in the sensitivity analysis including all generally healthy workers at baseline, cluster 2 (and a tendency for cluster 3 and 4) even showed lower risk of LTSA compared with cluster 1. Thus, a J-shaped association may exist between combined psychosocial work factors and risk of LTSA, as also indicated by the unadjusted data in figure 1. Thus, having one psychosocial 'challenge' - in the present case in terms of higher work pace (cluster 2), higher emotional demands (cluster 3) or lower recognition (cluster 4) - may be better than having no challenges at all, as long as the majority of the other psychosocial work factors are favorable. However, the J-shape may also be due to selection, as it is conceivable that more resilient employee chooses more challenging job tasks. While future studies should explore this J-shaped association in more detail, the present results suggest that scoring favorably on several psychosocial factors may outweigh the potentially adverse effects of scoring poorly on one or two factors. This has important practical implications, ie, workplaces may focus on aspects of the psychosocial work environment that are feasible to improve. For example, if emotional demands are difficult to reduce because of the inherent working conditions of dealing with patients and clients, sufficient recognition for the work, ensuring a high level of influence, securing collegial support, making the different roles clear, may be a way to reduce the risk of LTSA.

Although some of the nine included work environment factors may be more important than others, we treated all psychosocial work factors equally and did not weigh if the factor was about a potential stressor, (such as high emotional demands) or about a potential or lack of resource (such as collaboration and support from colleagues). The present data do not show a clear pattern indicating one or two "super factors" for the risk of LTSA, but rather an accumulative effect of more adverse factors increasing this risk. However, this should be replicated in future studies specifically designed to test this hypothesis.

Finally, interaction analyses suggest that gender, but not age and education, influenced the association between cluster and risk of LTSA. The most pronounced gender differences were that women (but not men) in cluster 2 - high work pace, but favorable scores on the other factors - had reduced risk of LTSA, while men (but not women) in clusters 7 and 8 - mixed scores of poor, moderate and favorable on the different psychosocial work factors - had increased risk of LTSA. As the labor market in Denmark is somewhat gender-segregated, eg, relatively more women in care work and more men in construction work, job-group specific clusters may be speculated to influence these findings. However, judging by the distribution of clusters within each job group (table 4), no clear indication of this exists. While the present study does not explain the cause of these genderdifferences, future studies should be cautious of testing for possible gender-interactions.

Limitations and strengths

We covered a large spectrum of the psychosocial work environment, by including nine different psychosocial work factors yielding 11 different clusters. However, we cannot claim the list of psychosocial factors to be exhaustive. The Danish Psychosocial Work Environment Questionnaire (DPQ) included 38 different psychosocial work factors (12). Several of these factors, eg, cognitive demands, were not measured in WEHD. Other factors were measured, but we decided not to include them in the analyses for the reasons explained in the introduction. Thus, data availability and assumption-based decisions limit the selection of work factors included in the present analysis.

Although we included factors related to theoretical models (eg, recognition as a part of the ERI model), our study was rather exploratory than theory driven. For example, we refrained from dichotomizing the 11 factors into demands versus resources, as suggested by the job-demands resources theory (38). Instead, we took a data-driven approach in identifying clusters most strongly associated with LTSA. We acknowledge that a more theory-driven approach would have likely resulted in different clusters. In addition, we measured four of the nine work factors with a single item only, which may have limited content validity. We would have preferred validated multi-item scales, like in the DPQ, but many of these were not available in WEHD. As the exposure variables on psychosocial work factors were self-reported, and we therefore chose an objective outcome measure, register-based LTSA, to avoid common-method biases. Nevertheless, some of the control variables were self-reported, e.g. mental health. As the state of mind may influence ratings of both psychosocial work factors and mental health, some misclassification bias may occur, ie, those with poor mental health may - everything else being equal - be more likely to rate the psychosocial work factors as worse. However, it may also be that poor working conditions had already led to poor mental health which in turn led to LTSA (mediation), and controlling the analyses for mental health may therefore have led to over-adjustment. In fact, poor mental health may act both as a confounder and mediator. For this reason, we also performed sensitivity analyses including only generally healthy individuals at baseline, which confirmed that the combination of many adverse psychosocial work factors (cluster 11) is associated with increased risk of LTSA. We did not include offending behaviors, such as workplace bullying, sexual harassment or violence, in the selection of cluster variables, because we did not want to mix factors that may have an immediate effect on health with other factors that may have a more long-term effect on health. This may pose a limitation because some of the highly unfavorable clusters could, speculatively, be clusters with a high prevalence of offending behaviors. The possibility also exists that factors at a higher hierarchical level, eg, leadership quality and behavior of the immediate supervisor or the top management, may have influenced several of the included factors. Further research should examine these aspects. Likewise, to circumvent some of the methodological limitations of the present study, future studies may consider using job-exposure matrices of clustering of psychosocial work factors as exposure variable and use diagnosed poor mental health obtained from registers (eg, depression) as a mediating factor in the risk of register-based absence from work or dropout from the labor market. However, such an approach is not without challenges, eg, register-based depression does not include undiagnosed cases. Furthermore, based on the distribution of clusters within job-groups (table 4), there may only be limited potential in constructing job-exposure matrices. Thus, job group differences for psychosocial work factors are not nearly as clear as those reported previously for physical workload (33). Using register-based LTSA as outcome also has some limitations. In Denmark, the cause of sickness absence is not registered (due to law). Thus, sickness absence from work can have several causes, including both work-related and non-work related diseases. In addition, we did not analyze short-term sickness absence or turnover. Nevertheless, LTSA is a good proxy of overall health that is strongly associated with adverse health endpoints in terms of disability pension and mortality (20). To ensure generalizable findings, the sample should be large and representative. In the present study, we used random samples of wage earners drawn over four different time points from 2012 to 2018. Further, we used model-assisted weight to ensure that estimates were representative. This strengthens the generalizability of the findings.

Concluding remarks

The combination of scoring poor on several psychosocial work factors plays an important role in the development of poor health in terms of LTSA. Importantly, scoring favorable on several psychosocial factors outweighed potentially adverse effects of scoring poor on one or two factors. This knowledge is of practical relevance especially for workplaces where the inherent conditions of the work make it difficult to improve all psychosocial work factors.

Data availability statement

The authors encourage collaboration and use of the data by other researchers. Data is stored on the secure server of Statistics Denmark, and researchers interested in using the data for scientific purposes should contact the authors.

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Conflicts of interest

The authors declare no conflicts of interest

Sidebar

Andersen LL, Vinstrup J, Thorsen SV Pedersen J, Sundstrup E, Rugulies R. Combined psychosocial work factors and risk of long-term sickness absence in the general working population: Prospective cohort with register follow-up

among 69 371 workers. Scand J Work Environ Health. 2022;48(7):549-559. doi:10.5271/sjweh.4035
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DETAILS

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Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability

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ABSTRACT (ENGLISH)

Objective The aim of this study was to investigate the contribution of work factors, health, and work ability to social inequalities in early exit from employment among older employees in Germany. Methods Longitudinal data from the representative German lidA Cohort study was linked with employment register data to obtain maximum information on exit routes out of paid employment. Information of N=2438 respondents, aged 46 and 52 at baseline, were obtained for a follow-up of six years (2011-2017). Causal mediation analysis with inverse odds weighting was conducted using discrete-time survival outcomes and baseline measurements of the socioeconomic status (SES: education), work factors, health, and work ability. Results Older employees with low SES were at an increased risk of exiting employment early by receiving disability pension and through long-term unemployment but not through an unspecified labor market exit when compared to those with high and moderate SES. Low work ability accounted for up to 38% of the social inequalities in work exits into disability pension. Less-than-good physical health accounted for up to 59% of inequalities in work exits into long-term unemployment. Work factors contributed considerably to inequalities in exits through unemployment but not disability pension. Conclusions This study finds social inequalities in early exits through disability pension and long-term unemployment among older employees in Germany, predominantly attributable to differences in work ability (disability pension) and physical health (unemployment). Investments in work ability and promotion of physical health may constitute promising approaches to counteract an increase of these inequalities.

FULL TEXT

Headnote

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Objective The aim of this study was to investigate the contribution of work factors, health, and work ability to social inequalities in early exit from employment among older employees in Germany.
Methods Longitudinal data from the representative German lidA Cohort study was linked with employment register data to obtain maximum information on exit routes out of paid employment. Information of N=2438 respondents, aged 46 and 52 at baseline, were obtained for a follow-up of six years (2011-2017). Causal mediation analysis with inverse odds weighting was conducted using discrete-time survival outcomes and baseline measurements of the socioeconomic status (SES: education), work factors, health, and work ability.
Results Older employees with low SES were at an increased risk of exiting employment early by receiving disability pension and through long-term unemployment but not through an unspecified labor market exit when compared to those with high and moderate SES. Low work ability accounted for up to 38% of the social inequalities in work exits into disability pension. Less-than-good physical health accounted for up to 59% of inequalities in work exits into long-term unemployment. Work factors contributed considerably to inequalities in exits through unemployment but not disability pension.
Conclusions This study finds social inequalities in early exits through disability pension and long-term unemployment among older employees in Germany, predominantly attributable to differences in work ability (disability pension) and physical health (unemployment). Investments in work ability and promotion of physical health may constitute promising approaches to counteract an increase of these inequalities.
Key terms inverse odds weighting; longitudinal cohort; older worker; social inequality.

In Germany, as in many other European countries, low-skilled workers drop out of the labor market earlier than highly-skilled workers (1). Recent pension reforms that aim to increase the statutory retirement age and sanction early exit routes out of paid employment will therefore affect this group more heavily, both in the short-term (eg, through loss of income) and the longterm (eg, through reduction in pension claims), when compared to those with higher socioeconomic status (SES) (2), thereby aggravating social inequalities in the work-retirement transition. For older employees with a lower SES, early exits from paid employment are rarely voluntary (1, 3) but may be the consequence of cumulative exposures to unfavorable working conditions, poor health and low work ability.

Socioeconomic inequalities in health are well documented (4). In Germany, this applies to both physical and mental health (5). Recent studies among older workers, strengthen the assumption of causation, ie, a low SES causes poor health (6). Health in turn plays a crucial role in the retirement behavior of older workers (7-10). Poor self-perceived general health, but also poor mental and physical health have been shown to be important risk factors for premature exits from paid employment due to disability pension and unemployment (9). Consistently, the risk of a health-based selection out of employment is most pronounced for those with a low SES (7, 8).

Not only health but also certain work factors are strongly associated with SES. Socioeconomic differences are frequently reported for physical but also psychosocial demands, such as quantitative demands and job control (6, 11, 12). Several studies have examined the effect of different work factors on premature exits from employment. Most recently, a study with data from the German Study on Mental Health at Work (S-MGA) found that employees exposed to awkward body postures, heavy lifting and high work pace were at an increased risk of early exit from employment (13). An earlier study based on data from the Survey of Health, Ageing, and Retirement in Europe (SHARE) demonstrated that a lack of job control increased the risk for disability pension, unemployment, and early retirement (14).

Next to health and the working conditions, the fit of the worker's resources and the work demands, which may be termed work ability (15), plays a crucial role in the timing of exit. Although evidence is scarce, workers with low SES seem to be at higher risk of experiencing low work ability (16, 17). Again, emerging evidence from Scandinavia, The Netherlands and most recently from Germany and the USA stress the predictive value of low work ability for early exits from work, most notably receiving disability pension (18-20), but also other exit routes, such as unemployment and inactivity prior to retirement (21).

Disability pension and unemployment are frequent early exit routes among older workers in Germany as other options, such as early old age pension, are only accessible to those aged >63 years with very long social security contributions (>45 or >35 years with deductions) (22-25). Another possible early exit route is often termed economic inactivity and is characterized by an unspecified early labor market exit (cf, 8, 11, 25).

So far, few studies have placed focus on the contribution of work factors, health, and work ability to social inequalities in early exit from employment during the later career of older workers. Existing studies on the topic have primarily focused on a different or reduced set of mediators in the pathway of the SES and early exit from paid employment and none included work ability (8, 11, 26). Moreover, none of the studies has a specific focus on older workers in Germany. Recent advancements in causal mediation analysis (27) are well suited to analyze pathways linking the SES to early exits. The so-called inverse odds (ratio) weighting (IO[R]W) (28) is fit for non-linear regression models including survival outcomes, agnostic with regard to exposure-mediator interactions on the outcome, and can accommodate multiple mediators simultaneously (unlike other counterfactual-based approaches) (29).

Using the IOW approach, we thus aim to examine the extent to which the effect of the SES (here: education) on early exit from paid employment operates through work factors, health, and work ability.

Based on the current evidence (8, 11, 26), we assume that the relevance of these pathways varies by the type of exit route and when comparing different social strata.

Methods

Study design and population

We use data from the German lidA study, which is a prospective cohort study on work, age, health and labor market participation. It is representative of socially insured older employees from the German "baby boom" generation with respect to sociodemographic variables such as sex, education and occupation, covering the birth cohorts 1959 and 1965 (30, 31). A detailed description of the study design and survey methods can be found elsewhere (30, 31). Currently the study comprises three waves with a baseline measurement in 2011 (N=6585) and two follow-ups (2014, N=4244; 2018, N=3586). The survey data was linked to employment register data from the Institute for Employment Research (IAB) of the German Federal Employment Agency to enrich information on employment histories and thereby on the potential exit routes and the timing of exit. This data covers information on employment status (excluding disability) of all employees subject to social insurance, thereby excluding sworn civil servants and self-employed.

All subjects who provided written consent for the usage of their employment register data during the last available survey wave were initially included in the present study (N=2560). The follow-up period was six years (2011-2017) with annual data on exits. Subjects who entered long-term unemployment or started to receive a disability pension in or before 2011, as well as subjects who experienced an unspecified labor market exit at some point in 2011 and subjects with missing data on the main exposure variable (education; N=15) were excluded, resulting in N=2438 matching cases between the two data sources (see supplementary material, www. sjweh.fi/article/4043, figure S1 for inclusion and exclusion criteria). Thus, the analysis only included subjects who were event-free at study baseline.

Early exit from paid employment

Three competing exit routes were defined, for which annual information was available: disability pension, long-term unemployment, and unspecified early labor market exit. Information on disability pension and unemployment events were obtained from the lidA survey data. If subjects received disability pension in 2018, they were asked to report when (year) they first entered the disability pension scheme. If subjects were unemployed in 2018, they were asked to report when (year) they left their last employment.

Information on unspecified early labor market exits was obtained from the employment register data. An unspecified early labor market exit was defined by a discontinuation of the individual's employment history in the register data (ie, exit from social insurance/gap spell). Only if subjects spent most of at least one year in this status (modal state), they were assigned this exit.

The time to the first event was recorded. Register data was available until 2017. Subjects with no event after exposure measurement in 2011 until the end of the follow-up period (2012-2017) were censored.

Socioeconomic status

SES was operationalized by the level of education, using a combined score of education and vocational training (32). The score was subsequently categorized into three classes of low (primary, lower secondary and upper secondary general education, cf. ISCED-97 1-3A), moderate (upper secondary vocational education and post-secondary non tertiary education, cf. ISCED97 3B-4A), and high education (tertiary education, cf. ISCED-97 5-6).

Work factors

In total, we assessed three work factors which, based on current evidence (6, 11-14), seemed to be plausible mediators between the SES and early exit from employment: physical demands, quantitative demands, and influence at work (as a proxy of job control). Physical demands were assessed with three items measuring the time exposed to awkward body postures, heavy lifting, and repetitive movements. Subjects exposed to any of the three dimensions for >25% of the working time were regarded as having high physical demands. Quantitative demands (low/high) and influence at work (low/high) were measured with items from the German version of the Copenhagen Psychosocial Questionnaire (COPSOQ) (33). The scales have been validated and show good psychometric properties (33). The resulting sum scores for each domain were subsequently dichotomized at the median.

Health

Physical and mental health were assessed using the Short Form Health Survey (SF-12) (34). Two separate sum scores were calculated for both health scales following Nübling, Andersen and Mühlbacher (35). Subsequently, they were dichotomized at the median, dividing the sample into groups of less than good versus good (mental or physical, respectively) health.

Work ability

The second dimension of the Work Ability Index (WAI2) (15) was used to parameterize work ability. WAI2 assesses the work ability in relation to mental and physical work demands with two items. A third item measuring whether subjects are mainly mentally or physically active in their jobs was used to weigh the responses to the first two items. The resulting sum score (2 [no work ability] to 10 [high work ability]) was dichotomized. The cut-off point was set at 8, defining subjects with low (<8) and high (>8) work ability. Ebener &Hasselhorn (36) validated the short measure and illustrated the advantages of its application in occupational health research.

Confounding variables

Age was assessed by the participants' birth year, resulting in two groups aged 46 (born 1965) or 52 (born 1959) at baseline (2011). Sex (male/female) and partner status (partnership/single) were dichotomous.

All covariates including the main exposure education were assessed at baseline in 2011. Since all included subjects were aged 46 or 52 at entry, it can be assumed that education preceded their work factors, health, and work ability at the time of the study.

Statistical analysis

Firstly, descriptive statistics were used to present the baseline characteristics of the study population and the number of early exits during the 6-year follow-up by educational level (table 1). Secondly, we estimated the main effects of the SES and the potential mediators on early exit from employment using Cox proportional hazard analyses (table 2). The proportional hazard assumption was checked based on Schoenfeld residuals (37). A respective P>0.05 indicates that the assumption of proportional hazards holds.

To examine the mediating effects of work, health, and work ability we applied an IOW approach to decompose the total effect (TE) of education on the outcome (ie, the survival time to the first exit event) into a natural direct effect (NDE) and natural indirect effect (NIE) (28, 29) (figure 1, tables 3-4). The NDE captures the effect of education on the outcome if the pathway through the mediator of interest was disabled, NIE the effect of education through the intermediate and TE the sum of NDE and NIE (38). The definitions of these effects estimates are based on the counterfactual framework (38, 39). We compared groups with low versus high and low versus moderate educational level.

In line with previous studies applying the IOW approach (12, 29, 40), the IOW estimation of NDE and NIE consisted of the following steps. First, a multino- mial regression model was fitted for education conditional on the mediator(s) and the confounding variables. Second, the individual's IOW was calculated by taking the inverse of the predicted odds from the first step. The reference group (first the high educated, then the moderate educated) was assigned with a weight equal to 1. Third, the TE was estimated by using a causespecific Cox regression model, regressing each exit route separately on education and the confounding variables. For this step, we declared the data to be survival-time data with Stata's "stset" command (37) without specifying a weight. Fourth, the NDE was estimated using the same model, but specifying the weights that were assigned to each subject in step 2. Lastly, the NIE was obtained by subtracting the NDE from the TE. We used bootstrapping with 1000 replications to derive the effect estimates and bias-corrected confidence intervals (CI) (41). Bias-corrected CI not including 1 indicate statistically significant effects and yield better coverage probabilities than normal approximation CI if the bootstrap distribution deviates from normal (41). A P<0.05 was considered statistically significant. Missing values of single variables did not exceed 5%. Hence, missing data were handled by listwise exclusion. The percentage of cases excluded did not exceed 2.4% in fully adjusted multi-mediator models. We calculated the proportion mediated (PM) using VanderWeele's (38) equation for ratio measures: HRNDE·(HRNIE-1)/(HRNDE·HRNIE-1). In order to compute the NDE and NIE we assumed the absence of unobserved confounding for (i) the exposureoutcome relationship, (ii) for the mediator-outcome relationship and (iii) for the exposure-mediator relationship. Additionally, the absence of (iv) a mediator-outcome confounder that is an effect of the exposure was assumed (29). All analyses were conducted using Stata V15.1 (StataCorp LLC, College Station, TX, USA).

Sensitivity analysis

We conducted a competing risk regression using the Fine &Gray (42) model, estimating the main effects of education and the covariates on the competing exit routes to assess whether using this model would have changed the estimates compared to the Cox model.

Ethical approval

The Ethics Committee of the University of Wuppertal approved the protocol for the lidA Cohort study [5 December 2008 (Sch/Ei Hasselhom) and 20 November 2017 (MS/BB 171025 Hasselhorn)]. All participants were informed about the aims and procedures of the study. In accordance with data protection requirements, verbal consent was required for participation at baseline and for each follow-up wave and written consent was required for data linkage.

Results

Main findings

We found a higher prevalence of high physical demands, low influence at work, less-than-good physical health and low work ability among subjects with low SES (table 1). High quantitative demands were more prevalent in groups with higher SES (table 1, see supplementary table S2 for the strength of these associations). Furthermore, a larger proportion of subjects with low SES (4.3%) started to receive disability pension when compared to moderate (2.6%)

or high (0.9%) SES groups. This similarly applied to becoming long-term unemployed during follow-up time, while no such social gradient was apparent with respect to unspecified premature labor market exits (table 1). In total, 11.7% exited employment early in the low SES group, 7.3% in the moderate SES group and 6.2% in the high SES group. When compared to subjects with a high SES, employees with a low SES had a more than four-fold instantaneous rate of exiting into disability pension (HR 4.62, 95% CI 1.75-12.22) and an almost threetimes higher rate of becoming long-term unemployed (HR 2.85, 95% CI 1.20-6.79) during the 6-year followup (table 2). Also, when compared to subjects with a moderate SES, those with a low SES had a significantly higher instantaneous rate of exiting into disability pension (HR 1.83, 95% CI 1.08-3.13) and a borderline significantly higher instantaneous rate of exiting into unemployment (HR 1.69, 95% 0.96-2.98) (table 2). Neither the SES nor any potential mediator exerted a statistically significant effect on unspecified labor market exit and hence mediation analysis was not conducted for this outcome. For all analysis models, the proportional hazard assumption was fulfilled (ph-test P-value >0.05).
Table 3 shows the effect decomposition of the TE of the SES on disability pension into a NIE and NDE using work factors, health, and work ability as mediators. When comparing low versus high SES groups, 23% of the effect of the SES on disability pension was mediated by low work ability. Taking health and low work ability together, these factors explained 27% of the social inequalities in early exits into disability pension comparing low to high SES groups. Social inequalities between groups of low and moderate SES could be explained to an even higher degree by work ability (38%) and by health and work ability combined (47%).
When investigating unemployment as the outcome (table 4), (borderline) significant NIE were observed for all mediators except quantitative demands. We found that physical health mediated the largest proportion (38%) of the effect of the SES on this exit route when comparing low versus high SES groups, followed by work ability (35%), mental health and influence at work (each 28%). Estimating the mediation effects of health and work ability combined, the PM was 43%. The PM fell to 34% when work factors were added (table 4, analysis 8). A similar pattern was observed comparing low versus moderate SES groups: 59% of the effect of the SES on long-term unemployment was explained by physical health, followed by physical demands (57%), work ability (54%), influence at work (46%) and mental health (44%). The combined mediation effect of health and work ability lead to a PM of 65%.

Sensitivity analysis

Using the Fine &Gray (F&G) competing risk regression to determine the main effects of education and the covariates on the probability of leaving employment through one of the competing exit routes did not reveal considerable differences compared to the Cox model (supplementary table S3). We note that the subdistribution HR from the F&G model are not directly comparable to the HR as they are on a different scale.

Discussion

Main findings

Among older workers, those with a low SES (operationalized by education) had an increased risk of exiting employment early through disability pension and by entering long-term unemployment but not through an unspecified premature labor market exit. The results suggest that for older workers in Germany, low work ability may be the most important pathway through which the SES exerts its effect on employment exits through disability pension, accounting for 23% of the social inequalities between low and high SES groups, and 38% between low and moderate SES groups.
With respect to becoming long-term unemployed, the effect of the SES on this exit route operates to a large extent through poor physical health, which accounts for 38% of social inequalities comparing low to high SES groups and 59% comparing low to moderate SES groups. The combined analyses of health and work ability consistently lead to the highest PM values. As much as 65% of the effect of the low versus moderate SES on long-term unemployment was mediated by the combination of health and work ability.
The study indicates that work factors, health, and work ability explain social inequalities in early exit from employment between low and moderate SES groups to a larger extent than the social inequalities between low and high SES groups.

Comparability with existing evidence

Our findings coincide with previous analyses by Robroek et al (11) and Schuring et al (8), who demonstrated that lower educated workers had an increased risk of leaving paid employment due to disability benefits and unemployment.

In our study, work ability turned out to be the main contributor to social inequalities in early exit through disability pension, while work factors and health played a minor role. Our findings thereby deviate from a similar study by Robroek et al (11), who found that selfperceived health mediated large parts of the effect of the SES on disability pension. Work ability was not investigated in that study. We assume two main causes of the predominant role of work ability and the minor role of health in our study. Firstly, continuing to work may be possible despite poor health, but difficult in the presence of low work ability. In a recent discussion paper (43), the authors stress that older workers with poor health may continue working if they have to for financial reasons, an argument applying specifically to those with low SES. Conversely, those experiencing low work ability may have no other option than to exit employment. This assumption is supported by existing evidence indicating a strong predictive value of low work ability for subsequent disability pension (18-20).

Secondly, in Germany, eligibility criteria for access to disability pension are formally based on the work ability of employees. Disability pension is not granted unless workers are incapable of working in any kind of job for more than three (full disability pension) or six hours per day (partial disability pension) (25).

When it comes to long-term unemployment, in our analysis health, work ability, and work factors significantly contributed to social inequalities in early exits. Physical health was the dominating mediator, with a proportion mediated of 38% between low and high SES groups. In a similar study (11), the mediating effect of self-perceived health on unemployment was smaller (9%). The differences between the studies may not only be explained by the different operationalization of health, but also by the age of the analysis samples. While Robroek et al (11) investigated workers aged 18-64 years, our sample consists of workers aged 46 and 52 years at baseline. The effect of poor health on exits into unemployment may be more pronounced for older workers, especially in the presence of unfavorable working conditions (44, 45).

Lastly, work factors, health, and work ability consistently explained social inequalities in early exits between low and moderate SES groups to a larger degree than inequalities between low and high SES groups. Comparable observations were made in a methodologically similar study investigating the outcome health among older workers (12). In our study, the set of investigated mediators mainly reflects aspects of the work and health domains. However, those with a high SES might differ from those with lower SES with respect to many further life aspects with potential influence on labor market participation. Eg, existing evidence suggests that those with higher SES also have a healthier lifestyle (11) and more stable employment relationships (46), both protective of early exit from employment.

Strengths and limitations

To our knowledge, this is the first study examining social inequalities in early exit from paid employment applying an IOW approach with discrete survival time data. An important strength of the IOW approach is that a causal interpretation of the effect estimates is possible irrespective of a potential exposure-mediator interaction (29).

A further strength of the study is the linkage between survey data and employment register data, whereby annual information on three early exit routes could be obtained. However, we would like to stress some limitations inherent with the longitudinal study design.

Compared to the initial lidA study sample, lower educated subjects (26% at wave 1) are slightly underrepresented in the current analysis sample (21%). The total effects of the SES on the three exit routes may therefore be underestimated, if lower educated are more likely to exit early, as similar studies indicate (11, 46). Additionally, a healthy worker effect may contribute to an underestimation of the mediation effects, especially of health variables. We also note that for some analyses relatively few events per independent variable were observed. This mainly applies to the fully adjusted multi-mediator models, where less than the recommended ten events per independent variable for Cox regression models (47) were reached. Thus, the respective effect estimates need to be interpreted

with caution.
A strength of this study is the focus on few age groups as the mechanisms leading to early exit and potentially to social differences in early exit may be assumed to be age related (3). This, however, limits the external validity of the results for other age groups (see above). Furthermore, the country-specific context regarding early exits may hamper the generalizability of our findings to non-German contexts (48).
Lastly, the causal interpretation of the NDE and NIE is based on the no-unmeasured confounding assumptions, which were formulated above. Leaving employment is a complex process (2). Although we adjusted for common outcome-mediator and mediator-outcome confounders, residual confounding cannot be ruled out. Concerning assumption 4, only the partner status is post-exposure and may violate the assumption. However, our analysis indicated that this mediator-outcome confounder is not statistically significantly associated with the exposure.
Implications
In times of extended working life policies, our findings highlight the necessity of investments into selective prevention of low work ability and poor physical health among (older) workers to forestall a widening of social inequalities in early exits through disability pension and long-term unemployment. So far, in many countries, extended working life policies do not sufficiently consider groups of workers with different needs and resources as well as cumulative (dis-)advantages over the life course (2).
The findings further implicate that preventive measures targeting these intermediates may be more effective leveling inequalities between the low and moderate SES groups and - to a much lesser extent - those between low and high SES groups. Differences in employment participation between older workers with low and high SES may thus be explained to a larger extent by a conglomeration of further unobserved factors. Future studies should make use of the advantages of the IOW approach to examine an even broader selection of intermediates collectively, including health behavior and employment arrangements.
Concluding remarks
Our findings indicate low work ability and less-thangood physical health may propel social inequalities in early exit from paid employment through disability pension and long-term unemployment among older workers. Work factors contributed considerably to social inequalities in exits through unemployment but not through disability pension. Current extended working life policies should be accompanied by preventive measures addressing these factors to counteract the increase of social inequalities during the later career of older employees.
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Competing interests
The authors declare no conflicts of interest.
Sidebar
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Lung cancer incidence among workers biologically monitored for occupational exposure to lead: a cohort study

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ABSTRACT (ENGLISH)

Objective Earlier studies have reported increased risks of lung, kidney and brain cancers for exposure to lead. The International Agency for Research on Cancer (IARC) Working Group evaluated inorganic lead and its compounds probably carcinogenic to humans. This study aimed to assess the association between blood lead level in occupational exposure and risk of lung cancer. Methods The study was based on the follow-up of lung cancer incidence during 1973-2014 among 20 729 employees biologically monitored for their occupational lead exposure in 1973-1983. Duration of employment in the monitored work was assessed using records from the Finnish Centre for Pensions; and potential confounding by other occupational carcinogens using longitudinal information on the occupation in censuses and the Finnish National Job-Exposure Matrix (FINJEM). Occupation- and gender-specific prevalence of regular tobacco smoking and the socioeconomic status were also utilized in the adjustments for potential confounding. Results Positive trends were found for the elevated blood lead levels on the lung cancer risk. Among employees with the duration of employment of ≥60 months, the relative risk (RR) of lung cancer was 1.72 [95% confidence interval (CI) 1.28-2.31] for mean blood lead 1.0-1.9 µmol/L and RR 2.63 (95% CI 1.71-4.05) for mean blood lead ≥2.0 µmol/L, compared with mean lead <0.5 µmol/L. The studied potential confounders did not explain the findings on the increased risk for lead exposure. Conclusions The current study lends support to the findings that exposure to lead increases lung cancer risk. Increased risks were seen already at rather low blood lead levels.

FULL TEXT

Headnote

Objective Earlier studies have reported increased risks of lung, kidney and brain cancers for exposure to lead. The International Agency for Research on Cancer (IARC) Working Group evaluated inorganic lead and its compounds probably carcinogenic to humans. This study aimed to assess the association between blood lead level in occupational exposure and risk of lung cancer.

Methods The study was based on the follow-up of lung cancer incidence during 1973-2014 among 20 729 employees biologically monitored for their occupational lead exposure in 1973-1983. Duration of employment in the monitored work was assessed using records from the Finnish Centre for Pensions; and potential confounding by other occupational carcinogens using longitudinal information on the occupation in censuses and the Finnish National Job-Exposure Matrix (FINJEM). Occupation- and gender-specific prevalence of regular tobacco smoking and the socioeconomic status were also utilized in the adjustments for potential confounding.

Results Positive trends were found for the elevated blood lead levels on the lung cancer risk. Among employees with the duration of employment of ≥60 months, the relative risk (RR) of lung cancer was 1.72 [95% confidence interval (CI) 1.28-2.31] for mean blood lead 1.0-1.9 µmol/L and RR 2.63 (95% CI 1.71-4.05) for mean blood lead ≥2.0 µmol/L, compared with mean lead <0.5 µmol/L. The studied potential confounders did not explain the findings on the increased risk for lead exposure.

Conclusions The current study lends support to the findings that exposure to lead increases lung cancer risk. Increased risks were seen already at rather low blood lead levels.

Key terms association; blood lead level; carcinoma of the lung; employee; lead compound; risk.

Studies on occupational exposure to inorganic lead have inconsistently reported increased risks of lung, kidney and brain cancers (1). On the other hand, increased risks were suggested at environmental exposure levels clearly lower than the occupational safety standards. In part, the excess risk within such low-dose populations could have been due to residual confounding from tobacco smoking histories. There was extensive evidence from animal experimental studies showing that lead compounds can induce kidney tumors and brain gliomas, and lead proved to be an effective renal carcinogen or tumor promoter (1). The International Agency for Research on Cancer (IARC) Working Group evaluated inorganic and its compounds probably carcinogenic to humans, Group 2A, based on sufficient evidence from animal studies and limited evidence from human studies.

It has been recommended to use blood lead cohorts in assessing human cancer risks in lead-exposed workers due to availability of reliable individual-level exposure measures (2). Since the IARC evaluation, follow-up studies of occupational cohorts with blood lead data from Australia (3), South Korea (4) and UK (5) have shown variable results. Blood lead from environmental exposures has also been further reported to correlate with all-cause, all-cancer and lung cancer mortality, adjusted for cigarettes smoked per day, alcohol consumption, poverty income ratio and several other potential confounders (6).

In Finland, a cohort of employees monitored for occupational exposure to lead has been collected (7, 8). The earlier Finnish follow-up studies of the cohort, available in the IARC evaluation, showed increased risks of lung and brain cancers (9, 10). This cohort participated in a recent multicenter cohort mortality study in three countries (USA, Finland, and UK); significant positive trends were found with increased blood level for overall mortality and for mortality from lung cancer, chronic obstructive pulmonary disease (COPD), stroke and heart disease (11). Updated cancer incidence follow-up of two cohorts (Finland and UK) documented positive associations with increasing blood lead level for several cancer types, including lung and brain cancer particularly in the Finnish material (12). Information for potential confounders was not available for the above multicenter studies.

The purpose of the current study was to assess the association between blood lead level in occupational exposure and risk of lung cancer. The study was based on the follow-up of lung cancer incidence in the Finnish cohort biologically monitored for their occupational exposure to lead, taking in account the exposure histories. Potential confounding by other occupational carcinogens were assessed using information on the occupation in censuses and the Finnish National JobExposure Matrix (FINJEM) utilizing longitudinal census records. Occupation- and gender-specific prevalence of regular tobacco smoking (hereafter: smoking prevalence) and the socioeconomic status (SES) were also utilized. There was an emphasis to assess risks already at rather low blood lead levels, and analyses were done using both external and internal comparison groups.

Methods

Study materials

The cohort includes employees with documented blood lead (BL) measurements at the Finnish Institute of Occupational Health (FIOH) in the period 1973-1983, based on laboratory reports and employer data. The employees were identified for the monitoring based by the occupational safety and occupational health organizations of the employer or initiatives of employers only. Monitoring and related exposure prevention and safeguarding were based on the legal framework for occupational safety that obliged the employer to conduct these actions. Finnish labor law mandated that if the BL of any worker in the workplace exceeded 1.9 pmol/L, then all employees in that workplace should have their BL measured. The most regular BL tests were taken from the lead battery industry, lead smelting and metal foundries (13). There were also workplaces from a variety of activities and industries, often with only few BL measurements from a workplace. The monitoring was performed also in lead-using workplaces where there was no appropriate information about the exposure levels of the employees. If the BL levels were lower than the action limits, no further follow-up was legally requested. The current study updates the cancer incidence follow-up information up to end of 2014.

The correctness of the personal identifiers was checked from the Population Information System (dvv. fi/vaestotietojarjestelma), digital and population data services agency; data checked 19 September, 2014), and the dates of potential emigration or death identified up to end of 2014. There were altogether 63 700 BL in the original data. Measurements records were excluded from the current study if (i) it was not possible trace the personal identifier, (ii) the person was <18 or >65 years at time of the measurement or (iii) the measurement was done for non-occupational reasons. There were 59 920 measurements from 20 752 employees after these exclusions.

Finally, we excluded 23 persons with incorrect personal identifiers, leaving altogether 20 729 employees in the final cohort (2408 women and 18 321 men). There are on average three BL measurements per person and only one measurement for about 60% of the cohort members. About 11% of the highest personal BL were >1.9 pmol/L and about 16% were <0.5 pmol/L corresponding BL levels in the Finnish general population during the monitoring period. In 1970-1973, mean BL was 0.58 pmol/L in men and 0.46 pmol/L in women; the range was 0.1-1.6 pmol/L (14). Incidence records of lung cancers were obtained for the cohort from 1973 up to end of 2014 from a linkage with the Finnish Cancer Registry, using the personal identifier as the key. ICD-10 codes C33 and C34 (lung, trachea or bronchus) were included in the linkage. Data on the occupation and SES were obtained from Statistics Finland data on censuses for years 1970, 1975, 1980, 1985 and 1990. In census 1970, the data on employment, main occupational activity, and education was collected from citizens of Finland. In later years, data were collected from multiple registers and other available electronic data sources. SES in 1975 was assessed in census records based on information of the main occupational activity, occupational status, education, and field of activity. Five classes were used in our analysis: (i) entrepreneurs and upper-level employees; (ii) lower-level employees; (iii) manual workers; (iv) students; and (v) unknown or missing SES. Information on employment periods for the cohort members were traced from the earnings and accrual register of the Finnish Centre for Pensions, including year 1961 or later (www.etk.fi/en/ services-for-experts/registers/register-descriptions). A graph on the timelines for information on BL measure- ments, on confounders, and on the outcome ascertainment is provided in the figure S1 of the supplementary material (www.sjweh.fi/article/4046).

FIOH permitted the use of the monitoring data (TTL/2/2014). The linkage between the cohort and the cancer registry files was based on the permit by the Finnish Institute for Health and Welfare (THL/738/5.05.00/2014; THL/1443/5.05.00/2020). The study materials had permits also by the Digital and population data services agency (VRK 1770/410/14), Statistics Finland (TK-53-796-15; TK-53-804-20) and Finnish Centre for Pensions (ETK 27.1.2015; ETK/ SUTI 19032). The study used only data from the register-based sources that were permitted by the above authorities, therefore evaluation by an ethical committee was not required.

Exposure assessments

Exposure to lead was solely based on individual BL measurements. Both maximum and mean BL as categorized as well as continuous were used in the analysis. The length of monitored employment periods was categorized to four groups (<6, 6-59, >60 months, unknown), enabling identification of short-term employment as well as tentative analysis by duration. The number of personal measurements was often small and employment periods often extended outside monitoring period 1973-1983. The duration of employment was unknown if no valid employment records were available in the pensions center. There was no further information on work tasks during the monitored employment periods, restricting use of more detailed cumulative exposure indices for lead.

Altogether 11 exposures were assessed from FINJEM as potential occupational confounder for lung cancers, based on the IARC classes 1 or 2A and findings from the initial study (9): asbestos, chromium, nickel, arsenic, cadmium, quartz dust, respirable dust, gasoline engine exhaust, diesel engine exhaust, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Exposures to these chemicals were assessed on the basis of the occupational group of the employees, available in population censuses carried out every five years in 1970-1990 and FINJEM (15, 16). The FINJEM exposure assessments uses a three-digit coding structure of the occupational groups, following closely the ISCO58 classification. Exposure assessment procedure was identical for all the subjects and was blind to lung cancer outcome. First, annual mean exposure of each selected chemical was defined as a product of probability and level of exposure for the five census years. In addition to true zero values in FINJEM, annual mean exposure of all the chemicals was set to zero in censuses where (i) the study subject had no occupation or occupation was unknown or (ii) SES was student, pensioner/retiree, unemployed or unknown. In 192 subjects, occupation was missing or unknown in all the five censuses. In occupational groups exposed to any of the 11 potential occupational confounder, prevalence of any exposure in censuses 1970-1990 ranged from 14% (arsenic) to 77% (respirable dust). More detailed information on exposure to confounders by mean BL classes are presented in supplementary table S1.

To assess cumulative exposure (CE) for the potential occupational confounders, the annual mean exposure values in the five censuses were used in the 25 calendar years 1968-1992 as follows. Occupational group in each census was based on personal activity in the last week or the main occupation of the census year. Occupation in each census 1970-1990 was assumed for census year plus two calendar years. Finally, CE was the sum of mean exposures in this period. In the case of end of follow-up prior to 1 January 1993, the end year and years thereafter were omitted from cumulative exposure.

Smoking prevalence was assessed based on regular smoking data in annual health surveys in 1978-1993 (17).

Statistical methods

Follow-up of lung cancer incidence was initiated in the standardized incidence ratios (SIR) analyses at time of the last personal measurement and closed at death, emigration, or end of the follow-up period, whichever came first. SIR of lung cancer were calculated by comparing the observed numbers in the cohort follow-up with the expected numbers of cancers by age, gender and (calendar) period based on the risks in the Finnish general population and assuming that the observed numbers followed Poisson distribution. In addition to the risk estimates by the BL categories, the P-value for a linear trend over BL categories was assessed with multivariable Poisson regression. These external comparisons were restricted to few descriptive analyses using only the BL data as the source of exposure. Internal comparisons of the lung cancer risks by BL level were done using Cox proportional hazards model (R Studio). In the internal analysis the follow-up time was closed for lung cancer cases at the diagnosis time of their first lung cancer; otherwise as in the external analysis. In the internal comparisons, the reference categories were formed based on the personal results (highest or mean BL) and the duration of the monitored employment period. For the categorical internal analyses, the data was condensed into four groups (0.0-0.4, 0.5-0.9, 1.0-1.9, and >2.0 pmol/L) based on the personal mean or maximum BL. BL indicators were modelled also as continuous variables using natural logarithms of BL. The models were adjusted for age, gender, SES, year of last personal measurement, and smoking prevalence. Furthermore, to test confounding due occupational exposure, continuous variables on cumulative exposure to eleven potential occupational carcinogenic FINJEM factors were used in separate models. Primarily, those occupational sures were informative as a confounder, if the adjustment for it changed the RR point estimate for the highest BL group (mean personal BL >2.0 pmol/L) by >5% [see (18)]. Lung cancer risk was described also by the lead industries with most regular monitoring due to high levels (lead battery industry, lead smelting, metal foundries).

Results

There were 644 842 person-years in the study. There was a small increase in the lung cancer risk in the whole cohort compared to the general population [SIR 1.23, 95% confidence interval (CI) 1.14-1.32; table 1]. The SIR was higher among women (1.96, CI 1.47-2.57) than men (1.19, 95% CI 1.10-1.29). In the lowest BL category - 0.0-0.4 pmol/L - the SIR was 0.81 (95% CI 0.62-1.04) and the risk increased statistically significant above unity for blood levels >1.0-1.4 pmol/L.

The risk increased slightly as longer follow-up times passed since the last personal measurement (table 2). In the shortest follow-up group, the only significantly increased SIR was seen in the BL level group 1.5-1.9 pmol/L, and the P-value for linear trend was 0.17. There was a clear trend in the lung cancer risk over the BL levels in the follow-up groups of 10-19 years and >20 year since the last measurement (the P-value for a trend was <0.0001).

The internal analysis, with similar adjustment, yielded stronger associations than the external SIR analysis (table 3). The personal mean BL also fitted slightly better than the highest value. The risk in association with lead was seen in both genders (P-value 0.41 for the interaction term for BL and gender). For most employees the duration of the monitored employment was at least five years. In workers with a very high BL value (average >2.0 pmol/L) the duration tended to be shorter than in others. The risk of lung cancer associated strongly with BL levels in the employees with the duration of employment in the monitored tasks being >60 months. However, the risk increased by the duration of employment also by other exposure categories for lead, and there was no indication of interaction in the lung cancer risk between the BL level and duration of employment.

The point estimate for the highest BL group (mean personal BL level >2.0 pmol/L) was 2.58 (95% CI 1.853.59) in the multivariable model without occupational confounders. Adjustment for the studied potential confounders sis not essentially affect the findings (table 4).

Table 5 presents results by most frequently monitored lead industries (lead battery manufacture, metal foundries, lead smelting). Due to small numbers, the two lowest exposure groups were combined in these analyses. The point estimates of lung cancer risk were seemingly a little higher for the lead battery industry than for other industries. The difference was not statistically significant (P=0.073 for the interaction term between BL and storage battery factories). There were no statistically significant interactions between the other main industry groups and BL level, either (P=0.61 between BL and metal foundries, P=0.71 between BL and the lead smelting; and P=0.27 between BL and other lead industries).

Discussion

Occupational exposure to lead, measured as BL levels, associated with the lung cancer risk in this study. The increased risk was seen already at rather low exposure levels compared with occupational exposure limit values, and there was no clear threshold value for the increased risk. Particularly high risks were seen in lead-exposed workers with a long duration of employment. The studied occupational carcinogens or tobacco smoking did not explain the risks associated with lead exposure.

The follow-up period was 24 years longer in this study than the initial follow-up published in mid-1990s (9) resulting in 690 incident lung cancers compared to initial 121 cases. The long follow-up time since the collection of the monitoring data was essential for the increased risk estimates for lead. Given the rather short monitoring period compared with the overall employment histories within the workplaces, the long follow-up time reduced potential for bias related to selection of healthy workers in the study. We could also reduce a possible systematic error for a follow-up study due to the incompleteness in the verification of the personal identifiers of the monitored employees in the retrospective data collection phase. The long follow-up time since the monitoring activity caused some limitations too: it was not possible to collect further information from the study subjects or their next-of-kins, or to assess from the available register-based data sources when the exposure to lead had possibly ended or use of lead ended in the workplaces. The lead exposure levels in the monitored workplaces had continuously decreased since 1960s and early 1970s (13, 19). After the monitoring period of the current study many workplaces had been closed down or stopped using lead or discontinued the monitoring activity due to other reasons (20). Lead exposure from environmental sources also decreased, particularly after reductions of lead content in gasoline and prohibition use of leaded gasoline in 1994. Also, possibilities for longer exposure assessment periods <2 pmol/L were reduced because the instructions to continued monitoring were directed mainly to preventing very high-level exposures.

In the initial follow-up study of this cohort, information on exposure histories and personal tobacco smoking were assessed in a nested case-control study (9, 13). Tobacco smoking habits and histories as well as detailed employment histories (employers, workplaces, occupations, descriptions of work tasks) were assessed from the study subjects or their next-of-kins with help of a questionnaire, and assessments of exposure histories were compiled based on the information on the collected employment histories, monitoring, and industrial hygienic data. Potential occupational confounders or risk modifiers were common in many tasks, eg, in metal foundries, lead smelting, and car repair. However, probability of exposure to confounders was assessed as low among heavily exposed workers in storage battery manufacturing. Efforts were made in the current study to assess potential occupational confounders using data on occupational groups from historical census records, combined with FINJEM; as well as assess duration of employment using the pension center records. We believe that these register-based data sources were very valuable for the long-term follow-up. Except the short-term workers, contrasts of lead exposure by average BL were remarkable even based on few or a single individual-level measurements, if the duration of the employment period was long [see (21)]. The monitored employees were from a variety of occupational activities with variable patterns in potential confounders. We did not see any remarkable confounding by the studied occupational carcinogens, and there was no clear interaction between BL and the industry for the lung cancer risk. Still, we cannot completely rule out some residual confounding, due to use of group-level job-exposurematrix data.

Tobacco smoking did not materially confound the risk associated with lead in the initial case-control study (9, 13). The unadjusted odds ratio (OR) for the highest personal BL category >2.0 pmol/l was 1.2 (95% CI 0.4-4.1), and the OR adjusted for tobacco smoking (based on smoking history data) and vital status was 1.5 (95% CI 0.4-5.8), respectively (9). Alcohol consumption did not play a role in the lung cancer risk in that study. Information on other lifestyles, eg, diet or body-mass index, was not available. It had also been demonstrated that tobacco smoking did not affect the BL levels in the general Finnish population; the average BL 0.62 pmol/L in smokers and 0.58 pmol/L in non-smokers (14). In the current study, control for tobacco smoking could be done using occupational- and sex-specific daily smoking prevalence. Even though the smoking prevalence associated with about an 11-fold statistically highly significant increase in the lung cancer risk in the age- and gender-adjusted model, it did not confound the result observed for lead. About 75% of cohort members were blue-collar workers and final results were adjusted also for the SES. Still, in the current study we cannot rule out possible residual confounding by tobacco smoking particularly in the very low BL levels, where also excess risks of lung cancer are rather small compared to the heavy occupational exposure.

Adjustment for the SES might have produced a risk of over adjustment. However, the comparable risk estimate for the mean personal BL >2.0 pmol/L as shown in table 3 (HR 2.58, 95% CI 1.85-3.59) was 2.62 (95% CI 1.88-3.65) without adjustment for the SES. The CI did not become wider, and we therefore consider the risk of over adjustment small. Moreover, adjustment for SES was justified as a surrogate of unmeasured lifestylerelated factors.

In the previously reported pooled analysis of employees biologically monitored for BL from Finland, UK and US there were statistically significant positive trends using the log of each worker's maximum BL value for mortality from lung cancer, chronic obstructive pulmonary disease (COPD), stroke and heart disease, while borderline significant trend were found for mortality from bladder cancer, brain cancer and larynx cancer (11). There was a significant interaction for lung cancer between the countries, however (UK positive trend, P=0.14; USA/Finland positive trends, P<0.0001). A more recent analysis of cancer incidence in the combined cohort from Finland and the UK also suggested associations with lung cancer. In the separate analysis, the risk was confined mainly to the Finnish cohort and only suggestive association was seen in the UK cohort (12). Because in the UK cohort the maximum personal BL was <10 pg/dL (about 0.48 pmol/L) for only 1% of the employees, comparisons in that study could not be done using a reference category with such a low BL as here.

Follow-up studies of occupationally exposed employees with BL data have been published also from Australia (3) and South Korea (4). In the Gwini et al study (3) there was a small increase in the lung cancer risk in the overall cohort and no risk in a small subgroup of employees in the high BL category (>30 pg/dL; corresponding roughly to >1.45 pmol/L) compared with the general population. There were limitations in the quality and nature of the original cohort records, which accord- ing to the authors may have influenced the outcome ascertainment. Kim et al (4) reported increased risk of lung cancer mortality among women but not men, based yet on small numbers of exposed cases.

In the study by Liao et al (22), an excess risk of lung cancer after controlling for smoking was found for men but not women. Wynant et al (23) found no elevation of lung cancer in exposed workers in a population-based case-control study in Montreal. No personal biological measurements were available in that study.

BL from environmental exposures correlated with lung cancer mortality after an adjustment for cigarettes smoked per day, alcohol consumption, poverty income ratio, urban-rural residence status, body mass index, gender and few other potential confounders related mainly to lifestyle (6). The mean BL level in the study was as low as 4.4 pg/dL (about 0.2 pmol/L). Information on exposure to other environmental pollutants, such as other metals or engine exhausts, was not available. Rhee et al (24) reported increased risks of lung cancer mortality for BL values mainly from environmental exposures. Increased BL levels studied ranged from <10 to >20 pg/ dL (about 0.48-0.97 pmol/L), and they associated with smoking status and gender. The lung cancer mortality risk was associated with BL among women but not men, after an adjustment for smoking status, median pack-years, serum cotinine and environmental tobacco smoke exposure, and several variables on population characteristics. The association between BL and lung cancer was restricted to current and former smokers; lung cancer risk was unusually low in lead-exposed nonsmokers. Therefore, the authors did not rule out residual confounding because of smoking. Effect modification between lead and tobacco smoking was seemingly also possible, but no formal analyses were provided.

The current study documents excess risk of lung cancer in workers occupationally exposed to inorganic lead. Compared to the initial study (9), the follow-up time is now reasonably long and number of cases large. Unlike follow-up of two cohorts (12), we could consider occupation- and gender-specific regular tobacco smoking and exposure to main occupational risk factors. Moreover, the Finnish data included relatively big internal low-exposure reference group. Thus, our study adds credibility into the findings of the earlier cohort studies.

Concluding remarks

The current study supports the findings from earlier studies suggesting that exposure to lead increases risk of lung cancer. The risk was observed with even rather low BL levels compared with the occupational exposure standards of the time of the study. The previous studies have reported increased risks of lead also for some primary sites of cancer other than lung, such as esophagus and brain cancers as well as lymphoma, and it would be important to study effects of lead also with those primary sites with help of information on exposure histories and potential confounders.

Conflicts of interest statement

The authors declare no conflicts of interest.

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Sidebar

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DETAILS

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Occupation and SARS-CoV-2 infection risk among workers during the first pandemic wave in Germany: potential for bias/Authors' response - Occupation and SARS-CoV-2 infection risk among workers during the first pandemic wave in Germany: potential for bias

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ABSTRACT (ENGLISH)

[...]this is a potentially very important paper, advancing the evidence in relation to occupational risk factors for infection. [...]in our study, we examined the proportion of tests conducted in each occupational group as part of the sensitivity analyses (see supplementary figure S1, accessible at www.sjweh.fi/article/4037). [...]different motivation for testing due to economic hardship in case of a positive test result is an unlikely explanation, because Germany has a universal healthcare system, including paid sick leave and sickness benefits for all workers (3). [...]we are not convinced that the testnegative design should be the 'gold standard' for studying risk factors for SARS-CoV-2 infections (15).

FULL TEXT

We read with great interest the paper by Reuter et al (1) on the differences in risk of SARS-CoV2 infection by occupation during the first pandemic wave in Germany. Occupation has been linked with differential risks of infection (2, 3) as well as severe disease and death (4, 5). Hence, this is a potentially very important paper, advancing the evidence in relation to occupational risk factors for infection.

This study makes use of an existing cohort (the German National Cohort - NAKO), with data from over 100 000 workers who were employed or self-employed and completed a COVID-19 questionnaire. SARS-CoV2 infection was assessed through a self-reported positive PCR test carried out in a doctors practice, test centre or in a hospital. The main analyses used a Poisson regression model to obtain incidence rates of infection by occupation, both crude and analyses adjusted for potential confounding factors (sociodemographic and employment related factors) were carried out.

Based on the results of the analyses, the authors conclude that (i) there were relatively high infection rates in healthcare and personal services but also in business management and business services, (ii) there were relatively low infection rates in manufacturing and production related occupations, and (iii) there was an inverse social gradient between occupational position and risk of infection, with higher risk in occupations with advanced tertiary degrees/managers.

Like other studies, these analyses found relatively high infection rates in essential occupations. However, important differences with other studies included the inverse social gradient and the relatively high infection rates in occupations with management responsibility and requiring higher degrees. The authors postulated a possible explanation for this finding, stating that managers in Germany may be at higher risk due to recreational ski trips. Although this may well be a partial explanation, we argue that there is a more likely explanation for the high rates in higher educated people and those working in the healthcare sector. These groups are more likely to have been tested, particularly during the early stage of the pandemic, compared to other occupations such as those working in manufacturing and production-related occupations. This could be due to differential access to testing due to employer requirements or financial restraints (especially at times when tests were not free for all in Germany 1) or different motivations for testing (due to lack of sick pay or self-employment). The authors estimate the infection rates using these positive tests as the numerator and the total cohort population (many of whom have never been tested) as the denominator. Therefore, if there is a differential likelihood of testing between different occupations, this would lead to bias in the results.

It is relatively simple to address this problem by using a test-negative design (6, 7), which is a type of case-control approach where those with a positive test are compared to those who have tested negative (ie, excluding those who have never been tested). This has been widely used as the gold standard method for studying vaccine effectiveness (8) and is increasingly being used to study risk factors for COVID-19 infection.

We would encourage the authors to carry out such analyses and present the results in their response to this letter. If, as we expect, the high relative risks in those with higher education and/or managers are reduced in these analyses, this would strongly indicate that the reported findings are primarily due to selection bias.

We thank van Tongeren et al for responding to our study on occupational disparities in SARS-CoV-2 infection risks during the first pandemic wave in Germany (1). The authors address the potential for bias resulting from differential testing between occupational groups and propose an alternative analytical strategy for dealing with selective testing. In the following, we want to discuss two aspects of this issue, namely (i) the extent and reasons of differential testing in our cohort and (ii) the advantages and disadvantages of different analytical approaches to study risk factors for SARS-CoV-2 infection.

Our study relied on nationwide prospective cohort data including more than 100 000 workers in order to compare the incidence of infections between different occupations and occupational status positions. We found elevated infection risks in personal services and business administration, in essential occupations (including health care) and among people in higher occupational status positions (ie, managers and highly skilled workers) during the first pandemic wave in Germany (2). Van Tongeren's et al main concern is that the correlations found could be affected by a systematic bias because people in healthcare professions get tested more often than employees in other professions. A second argument is that better-off people could be more likely to use testing as they are less affected by direct costs (prices for testing) and the economic hardship associated with a positive test result (eg, loss of earnings in the event of sick leave).

We share the authors' view that differential testing must be considered when analysing and interpreting the data. Thus, in our study, we examined the proportion of tests conducted in each occupational group as part of the sensitivity analyses (see supplementary figure S1, accessible at www.sjweh.fi/article/4037). As expected, testing proportions were exceptionally high in medical occupations (due to employer requirements). However, we did not observe systematic differences among nonmedical occupations or when categorising by skill-level or managerial responsibility. This might be explained by several reasons. First, SARS-CoV-2 testing was free of charge during the first pandemic wave in Germany, but reporting a risk contact or having symptoms was a necessary condition for testing1. The newspaper article cited by van Tongeren et al is misleading as it refers to a calendar date after our study period. Second, different motivation for testing due to economic hardship in case of a positive test result is an unlikely explanation, because Germany has a universal healthcare system, including paid sick leave and sickness benefits for all workers (3). Self-employed people carry greater financial risks in case of sickness. We therefore included self-employment in the multivariable analyses to address this potential source of bias.

While the observed inverse social gradient may be surprising, it actually matches with findings of ecological studies from Germany (4, 5), the United States (6, 7) as well as Spain, Portugal, Sweden, The Netherlands, Israel, and Hong Kong (8), all of which observed higher infection rates in wealthier neighbourhoods during the initial outbreak phase of the pandemic. One possible explanation is the higher mobility of managers and better educated workers, who are more likely to participate in meetings and engage in business travel and holiday trips like skiing. Given the increasing number of studies providing evidence for this hypothesis, we conclude that the inverse social gradient in our study likely reflects different exposure probabilities and is not a result of systematic bias. This also holds true for the elevated infection risks in essential workers, which is actually corroborated by a large body of research (9-11).

Regarding differential likelihood of testing, van Tongeren et al state that "[i]t is relatively simple to address this problem by using a test-negative design" (1). As van Tongeren et al describe, this is a case-control approach only including individuals who were tested (without considering those who were not tested). However, the proposed analytical strategy can lead to another (more serious) selection bias if testing proportions and/or testing criteria differ between groups (12). This can be easily illustrated when comparing the results based on a time-incidence design with those obtained by a testnegative design as shown in table 1.

Both approaches show similar results in terms of vertical occupational differences. Infection was more common if individuals had a high skill level or had a managerial position, but associations were stronger in the time-incidence design and did not reach statistical significance in the test-negative design (as indicated by the confidence intervals overlapping "1"). Unfortunately, the test-negative approach relies on a strongly reduced sample size and thus results in greater statistical uncertainty and loss of statistical power (13). In contrast, the test-negative design yields a different picture when estimating the association between essential occupation and infection risk: In this analysis, essential workers did not differ from non-essential workers in their chance of being infected with SARS-CoV-2 (the test-negative design even exhibits a lower chance for essential workers). This is rather counter-intuitive and is not in accordance with what we know about the occupational hazards of healthcare workers during the pandemic (14). The main problem is that proportions of positive tests are highly unreliable when testing proportions and/or testing criteria differ between groups. As essential workers were tested more often without being symptomatic (due to employer requirements), a lower proportion of positive tests in this group does not necessarily correspond to a lower risk of infection.

Consequently, we are not convinced that the testnegative design should be the 'gold standard' for studying risk factors for SARS-CoV-2 infections (15). Especially problematic is the loss of statistical power (increasing the probability of a type II error) and the low validity of the test-positivity when test criteria and/ or test proportions differ between groups.

Sidebar

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Footnote

1.https://www.reuters.com/business/healthcare-pharmaceuticals/ germany-offer-free-covid-19-tests-saturday-2021-11-12/

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1. https://www.bundesgesundheitsministerium.de/coronavirus/ chronik-coronavirus.html (accessed 5 September 2022).
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DETAILS

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Tucker, P. (2022). Scientific challenges of studying shift schedule design. Scandinavian Journal of Work, Environment & Health, 48(7), 507-510. doi:https://doi.org/10.5271/sjweh.4058

The study of shift schedule design, and its impact on the health, safety and the performance of shiftworkers, has seen considerable advances in methodology in the last decade. Much of the early research that helped identify shift schedule design principals was based on observational studies. Quite many featured cross-sectional designs that were subject to residual confounding from unadjusted potential confounders. Moreover, the early studies were almost universally based on self-reported exposure and many relied upon self-reported outcomes, making them subject to information bias. Researchers have since built on the findings of earlier research with more sophisticated and robust designs and metrics, many of which are exemplified in studies that have been published in this journal. These provide a firmer evidence base on which to develop recommendations for the design of shift schedules. Here, several methodological approaches in the study of shift schedule design are discussed.

Würtz, A. M., PhD, Kinnerup, M. B., PhD., Pugdahl, K., PhD., Schlünssen, V., MD, Vestergaard, J. M., Nielsen, K., PhD., . . . Kolstad, H. A., M.D. (2022). Healthcare workers' SARS-CoV-2 infection rates during the second wave of the pandemic: Follow-up study. Scandinavian Journal of Work, Environment & Health, 48(7), 530-539. doi:https://doi.org/10.5271/sjweh.4049

Objectives This study aimed to assess if, during the second wave of the COVID-19 pandemic, healthcare workers had increased severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection rates, following close contact with patients, co-workers and persons outside work with COVID-19. Methods A follow-up study of 5985 healthcare workers from Denmark was conducted between November 2020 and April 2021 and provided day-to-day information on COVID-19 contacts. SARS-CoV-2 infection was defined by the first positive polymerase chain reaction (PCR) test ever. Data was analyzed in multivariable Poisson regression models. Results The SARS-CoV-2 infection rates following close contact 3-7 days earlier with patients, co-workers and persons outside work with COVID-19 were 153.7, 240.8, and 728.1 per 100 000 person-days, respectively. This corresponded with age, sex, month, number of PCR tests and mutually adjusted incidence rate ratios of 3.17 40 cases, 95% confidence interval (CI) 2.15-4.66], 2.54 (10 cases, 95% CI 1.30-4.96) and 17.79 (35 cases, 95% CI 12.05-26.28). The risk of SARS-CoV-2 infection was thus lower, but the absolute numbers affected was higher following COVID-19 contact at work than COVID-19 contact off work. Conclusions Despite strong focus on preventive measures during the second wave of the pandemic, healthcare workers were still at increased risk of SARS-CoV-2 infection when in close contact with patients or co-workers with COVID-19. There is a need for increased focus on infection control measures in order to secure healthcare workers' health and reduce transmission into the community during ongoing and future waves of SARS-CoV-2 and other infections.

Kader, M., PhD., Selander, J., PhD., BSc, T. A., Albin, M., M.D., Bodin, T., M.D., Härmä, M., MD, . . . Bigert, C., M.D. (2022). Night and shift work characteristics and incident ischemic heart disease and atrial fibrillation among healthcare employees - a prospective cohort study. Scandinavian Journal of Work, Environment & Health, 48(7), 520-529. doi:https://doi.org/10.5271/sjweh.4045

Objective This study aimed to examine the effects of various aspects of night and shift work on the risk of incident ischemic heart disease (IHD) and atrial fibrillation (AF) using detailed and registry-based exposure data. Methods This prospective cohort study included >30 300 healthcare employees (eg, nurses, nursing assistants) employed for at least one year in Region Stockholm 2008-2016. Information on daily working hours was obtained from a computerized administrative employee register and outcomes from national and regional registers. Using discrete-time proportional hazard models, we analyzed the outcomes as functions of working hour characteristics the preceding year, adjusted for sex, age, country of birth, education, and profession. Results We observed 223 cases of IHD and 281 cases of AF during follow-up 2009-2016. The risk of IHD was increased among employees who the preceding year had permanent night shifts compared to those with permanent day work hazard ratio (HR) 1.61, 95% confidence interval (CI) 1.06-2.43] and among employees working night shifts >120 times per year compared to

those who never worked night (HR 1.53, 95% CI 1.05-2.21). When restricted to non-night workers, the risk of IHD was increased for employees having frequent quick returns from afternoon shifts. No increased risks were observed for AF. Conclusions Night work, especially working permanent night shifts and frequent night shifts, is associated with an increased risk of incident IHD but not AF. Moreover, frequent quick returns from afternoon shifts (among nonnight workers) increased IHD risk. Organizing work schedules to minimize these exposures may reduce IHD risk.

Mehta, A. J., Mathisen, J., Nguyen, T., Rugulies, R., & Rod, N. H. (2022). Chronic disorders, work-unit leadership quality and long-term sickness absence among 33 025 public hospital employees. Scandinavian Journal of Work, Environment & Health, 48(7), 560-568. doi:https://doi.org/10.5271/sjweh.4036

Objective This study aimed to examine the association between work-unit level leadership quality and individual-level long-term sickness absence (LTSA) in the hospital sector and effect modification by chronic disorders. Methods This longitudinal analysis included 33 025 Danish public hospital employees who were followed-up for one year after baseline in March 2014. Leadership quality was assessed by questionnaire with mean responses aggregated by work-unit and characterized in tertiles. LTSA during follow-up was determined from employer records. Chronic disorders at baseline was assessed from the Danish hospital and prescription registers. We performed multilevel logistic regression to estimate odds ratios (OR) and 95% confidence intervals (CI) adjusting for potential confounders. We evaluated interaction between chronic illness and low leadership quality on multiplicative and additive scales. Results We identified employees as healthy (60.8%) or with somatic (31.6%), mental (3.3%), or both somatic and mental (4.3%) disorders. During follow-up, 6% of employees registered a LTSA. Medium and high leadership quality were associated with lower risk of LTSA with OR of 0.84 (95% CI 0.76-0.94) and 0.73 (95% CI 0.65-0.82) respectively, compared to low leadership quality. Associations were similar for healthy employees and employees with only somatic disorders, whereas no association was observed for employees with mental disorders (in presence or absence of somatic disorders). No statistically significant (a=0.05) interactions between leadership quality and chronic disorders on LTSA were observed. Conclusion The findings suggest that the quality of leadership in work units is associated with risk of long-term sick leave in the Danish public hospital sector and that strong leadership protects employees against LTSA.

Roelen, C. A. M., PhD., Speklé, Erwin E M, PhD, Lissenberg-Witte, B., Heymans, M. W., PhD., van Rhenen, W., PhD, & Schaafsma, F. G., PhD. (2022). Predicting long-term sickness absence among retail workers after four days of sick-listing. Scandinavian Journal of Work, Environment & Health, 48(7), 579-585. doi:https://doi.org/10.5271/sjweh.4041

Objective This study tested and validated an existing tool for its ability to predict the risk of long-term (ie, >6 weeks) sickness absence (LTSA) after four days of sick-listing. Methods A 9-item tool is completed online on the fourth day of sick-listing. The tool was tested in a sample (N=13 597) of food retail workers who reported sick between March and May 2017. It was validated in a new sample (N=104 698) of workers (83% retail) who reported sick between January 2020 and April 2021. LTSA risk predictions were calibrated with the Hosmer-Lemeshow (H-L) test; non-significant H-L P-values indicated adequate calibration. Discrimination between workers with and without LTSA was investigated with the area (AUC) under the receiver operating characteristic (ROC) curve. Results The data of 2203 (16%) workers in the test sample and 14 226 (13%) workers in the validation sample was available for analysis. In the test sample, the tool together with age and sex predicted LTSA (H-L test P=0.59) and discriminated between workers with and without LTSA AUC 0.85, 95% confidence interval (CI) 0.83-0.87]. In the validation sample, LTSA risk predictions were adequate (H-L test P=0.13) and discrimination was excellent (AUC 0.91, 95% CI 0.90-0.92). The ROC curve had an optimal cut-off at a predicted 36% LTSA risk, with sensitivity 0.85 and specificity 0.83. Conclusion The existing 9-item tool can be used to invite sick-listed retail workers with a ≥36% LTSA risk for expedited consultations. Further studies are needed to determine LTSA cut-off risks for other economic sectors.