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ORIGINAL ARTICLE

Tip of the iceberg: unveiling the impact on back disorders from cumulative physical job exposure and evaluating bias from the healthy worker effect using a nationwide longitudinal cohort study

Amalie Wiben[1] · Christian Skovsgaard[1] · Karen Søgaard[2] · Berit Schiøttz-Christensen[3] · Kim Rose Olsen[1]

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Abstract

Purpose Longitudinal studies across various sectors with physically demanding jobs are notably absent in back disorder risk research. This study aimed to investigate the relationship between cumulative physical job exposure (PJE) and hospital-diagnosed back disorders among individuals in Denmark. To assess the healthy worker effect, we compared the cumulative risk estimate with results from a naive cross-sectional model ignoring PJE history.

Methods A nationwide longitudinal cohort study was conducted using Danish registers, encompassing individuals born between 1975 and 1978 and working in 1996. Cumulative PJE was measured with a 10-year look-back period for each year 2006–2017. PJE consisted of lower-body occupational exposures, including the total weight lifted, stand/sit ratio, and the frequency of lifting more than 20 kg per day from a job exposure matrix. Odds ratio for back disorders was estimated for each year and all years combined.

Results The results unveiled a significant 31% increase in the risk of hospital-diagnosed back disorders after 4 years of cumulative PJE. The lowest risk (7%) was observed for incident back disorders with 1 year of exposure, suggesting a healthy worker effect. Nevertheless, this risk is still significantly elevated. This cumulative estimate is fourfold the estimate from the 2006 naive cross section model.

Conclusion Our study clearly demonstrates an 31% increase in the risk of hospital-diagnosed back disorders with just 4 years of PJE over a 10-year period. Further, we find that cross-sectional studies strongly underestimate the risk of back disorders due to the healthy worker effect.

Keywords Job exposure · Back disorder · Physical work · Longitudinal study · Register study

Abbreviations

DaRD	Danish spine database/register
HWE	Healthy worker effect
PJE	Physical Job Exposure
CRS	Danish civil registration system
NPR	National patient register
JEM	Job exposure matrix
DOC*X Database	Danish occupational cohort with exposure data
DISCO-88	Danish version of the international standard classification of occupation
D(letter)(number)	Danish version of ICD-10 (version 2016)

✉ Amalie Wiben
awiben@health.sdu.dk

1 Danish Centre for Health Economics, Department of Public Health, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark

2 Research Unit of Physical Activity and Health in Working Life, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark

3 Research Unit of General Practice, Department of Public Health, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark

Introduction

Back disorders are a huge public health problem, limiting productivity at work and imposing a substantial socioeconomic burden on society [1]. Each year 15–20% of adults

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suffer from back pain, and 50–80% experience at least one episode of back pain during their lifetime [2] leading to greater difficulties in meeting physical work demands and thereby challenging their capacity to participate in full-time employment [3]. With expectations of an increasing retirement age in most countries, the burden from back disorders will continue to increase [4]. In Denmark alone, the prevalence of back disorders in 2017 was approximately 20% of the population aged 16 and above [5].

Back disorders are rarely attributed to a specific pathology. In this study, back disorders are defined as per the Danish Spine Database and encompass a wide range of hospital-diagnosed conditions affecting the back [6]. By using only hospital-diagnosed back disorders, we generate a conservative estimate of the prevalence of back pain. However, it has the advantage of high precision when it comes to estimating severity [7].

Numerous studies have explored the association between specific occupations and back disorders, primarily focusing on non-sedentary professions such as health service workers, social workers, and blue-collar workers. These studies generally conclude that employees with a strenuous physical workload face a higher risk of back disorders [8–14]. However, these studies suffer from several limitations. Firstly, they rely on questionnaires and small sample sizes that increase the risk of recall and selection bias. Secondly, many studies have centred on nonspecific back pain symptoms or self-rated back disorders, which makes the diagnosis uncertain. Thirdly, few studies use longitudinal data and therefore fail to capture the healthy worker effect (HWE) and thereby underestimate the risk of back disorders. Hartvigsen et al. [13] utilized data from two survey waves that identified the HWE and demonstrated a trend where individuals experiencing low back pain over time transition into sedentary occupations. This shift may lead to a downward bias in the risk associated with physical job exposure (PJE) and, conversely, an upward bias in the risk associated with sedentary occupations.

Objective

This study's objective is to examine the relationship between cumulative PJEs estimated over a 10-year period at yearly intervals from 2006 to 2017 and hospital-diagnosed back disorders. In addition, we hypothesized that an increase in cumulative PJE will increase the risk of hospital-diagnosed back disorder. To assess the magnitude of the HWE, we compared the risk from cumulated PJE with the risk from naive cross-sectional models.

Methods

Design and population

A longitudinal nationwide cohort study was conducted using data from Danish registers, specifically the Danish Civil Registration System (CRS) [15], and the National Patient Register (NPR) [16], along with a job exposure matrix (JEM) based on experts' ratings of occupational lower-body exposures from the DOC*X database [17, 18].

The cohort included individuals born between 1975 and 1978 (18–21 years of age in 1996). We chose a younger population cohort to mitigate healthy worker bias, since younger individuals are less likely to have experienced back disorders and, therefore, less likely to have migrated into sedentary occupations to avoid back-related concerns. Further, the individuals must have a valid annual job code according to DISCO-88 in 1996 to ensure they have entered the labour market. We excluded individuals from the cohort if (1) they had any hospital-diagnosed back disorder before December 31, 2005, or (2) if they died or emigrated between 1st January 1996 and 31st December 2017. The final cohort included 129,179 individuals. (The flowchart is shown in Fig. 1).

Individuals were followed from 1 January 2006, until the date of hospital-diagnosed back disorder, retirement, or censoring due to the end of the study by 31 December 2017 (whichever came first). In total, we observed 20,854 incidents (16%) of hospital-diagnosed back disorders during the period 2006–2017.

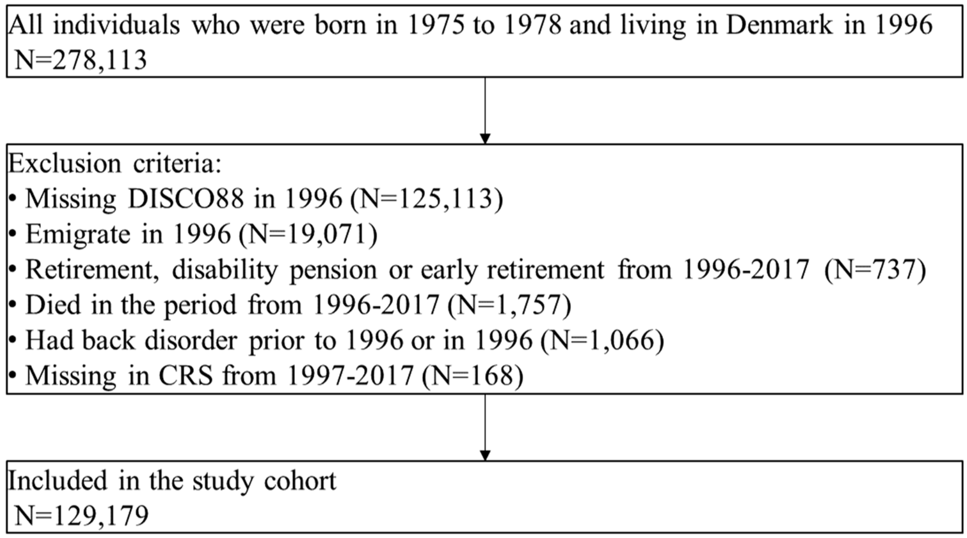
To assess the cumulative exposure of each cohort member, we calculated the cumulative PJEs over a 10-year look-back period (2006–2017) with a 1-year lag at each year. This approach allowed us to establish a long-term perspective on PJE in the hopes of better understanding the relationship between accumulated physical workload, back disorders, and the influence of the healthy worker effect. Further details are provided in the section below.

Exposure

Information regarding individuals' year-by-year occupational history, specifically the DISCO-88 codes spanning from 1996 to 2017, was obtained from the DOC*X database [18]. In cases where DISCO-88 codes were missing, i.e. when individuals were unemployed or job codes were unknown, zero exposure was assigned. DISCO-88 codes were subsequently converted into PJE estimates utilizing the lower-body JEM [17].

The lower-body JEM encompasses ratings of various daily PJEs, done by occupational medicine specialists. In this study, we used the total load lifted in kilograms (kg) (Total Load), the stand/sit ratio (Stand/Sit ratio), and number

Fig. 1 Flowchart



of times lifting more than 20 kg per day (Times > 20) as exposure measures. Individuals had to be exposed to all three exposure measures to be counted as exposed. Notably, the lower-body JEM has previously demonstrated predictive validity for multiple outcomes, e.g. risk of total hip replacement and risk of acute myocardial infarction [19, 20], but has never been used to assess the risk of back disorders. The JEM is based on the complete set of currently utilized job titles in the Danish version of the International Standard Classification of Occupation (DISCO-88) on one axis, and ratings of specific lower-body exposures on the other [18]. In Denmark, occupational medicine specialists possess expertise in quantifying the physical exposures during a typical workday across various occupations, as their detailed documentation forms the basis for compensation regarding back disorders [20].

Outcome

The outcome of interest in this study was incident hospital-diagnosed back disorders, which were defined by a hospital admission with an ICD-10 code specifically related to back disorders as outlined in the Danish Spine Register (DaRD) [6]. Information pertaining to the specific type and date of the hospital diagnosis was obtained from the NPR. The following primary diagnostic codes were included: DM42*, DM43*, DM47*, DM48*, DM495, DM50*, DM51*, DM53*, DM54*, DM809C, DM96*, DM99*, and DS13*.

Confounder variables

Several confounder variables were accounted for, including sex, age, calendar year, higher education, and region of residence. The inclusion of region of residence aimed to capture regional variations in diagnosis rates, considering that regions are responsible for the secondary sector in Denmark and to capture regional variation in exposure.

Statistics

We employed a logistic regression, specified as a discrete survival analysis, to calculate the cumulative risks for incident hospital-diagnosed back disorder [21]. The risks are measured as odds ratios (OR), which can be interpreted as a hazard ratio. The statistical unit in this approach was person-years. Cumulative exposures measured using a 10-year look-back window for each follow-up year (2006–2017) were utilized. In the adjusted models, we controlled for sex, age, higher education, region of residence (five categories), and year. Error terms were clustered at the individual level.

We did a range of supplementary analyses to assess the magnitude and impact of the HWE. First, we illustrated the magnitude of the HWE in our sample by showing the number of healthy survivors in PJE occupations over the period 2006–2017 for all individuals exposed in year 2006. Second, we compared the estimated cumulated risks with the naive cross section estimate from year 2006. Third, we ran the adjusted regressions year by year throughout the entire study period (2006–2017).

Individuals enrolled as students during the study period, but also holding part-time or full-time employment, were assigned a PJE based on their student occupation. By nature, most of these occupations will be part-time and the PJE might be limited, so to test the robustness to this uncertainty we attributed an exposure value of 0 in these cases, despite knowing their DISCO code. A further rationale for this adjustment was grounded in the expectation of minimal exposure among students.

The analyses were performed using Stata v.18 on Statistics Denmark's research platform. STROBE guidelines were employed.

Results

Table 1 presents the characteristics of all person-years across the PJE. The table shows that there are more males (61.1%) than females (38.9%) exposed to physical work. Regional differences are also evident, especially for the capital region where 25.6% were exposed and 35.8% were not. The majority (87.9%) of those exposed to physical work have a secondary education level, while 7.9% have a high education level, indicating that individuals with higher education are underrepresented in the exposure group. Among self-employed individuals, 4.4% were exposed, while 3.3% were not. For students, the table shows that 8.5% were exposed and 10.5% not.

Figure 2 presents the ORs for incident hospital-diagnosed back disorder in relation to cumulated PJE years. In both the crude and adjusted model, we see that the OR peaks around four years of cumulated exposure. ORs were slightly lower in the adjusted model primarily due to the adjustment for higher education. We observe that with just one year of PJE, the OR is significantly increased (OR 1.07, 95% CL 1.00–1.15, adjusted model, see also Table 2 in the appendix) and peaks at 4 years of cumulative exposure (OR 1.31, 95% CI 1.21–1.41, adjusted model). After 4 years the OR steadily declines until ten years of exposure (OR 1.14, 95% CI 1.07–1.21, adjusted model).

Table 1 Descriptive Statistics. Characteristics of 2,620,705 person-years (1996–2017) according to physical job exposure. Exposures were estimated using the lower-body JEM

Physical job exposure	Total	Unexposed	Exposed
N	2,620,705	1,500,157	1,120,548
Sex			
Male	50.2%	42.0%	61.1%
Female	49.8%	58.0%	38.9%
Age	29.8174	30.6967	28.6403
Residence region			
Capital region	31.5%	35.8%	25.6%
Region Zealand	14.1%	13.8%	14.6%
Region of Southern Denmark	20.7%	18.7%	23.3%
Region of Central Denmark	23.3%	22.2%	24.7%
Region of Northern Denmark	10.5%	9.5%	11.8%
Socioeconomic status			
Self employed	3.8%	3.3%	4.4%
Employed	79.3%	75.1%	84.8%
Unemployed[a]	7.3%	11.0%	2.3%
Students	9.7%	10.5%	8.5%
Highest level of education			
Vocational education	3.1%	2.2%	4.2%
Secondary education	76.8%	68.5%	87.9%
Higher education	20.2%	29.3%	7.9%

[a]Due to the use of different registries, it is possible in this table to be unemployed and exposed. This does not affect the results

Healthy worker effect

Figure 3 presents how the exposed persons in 2006 migrate to unexposed (sedentary) occupations over time. The figure shows that 2/3 of the initially exposed individuals are no longer occupied in exposed occupations by 2017. Hence, only 1/3 are healthy survivors.

In Fig. 4 we compare the baseline results with a naive cross section approach for the year 2006 disregarding the cumulative exposure, hence only looking at exposure in 2005. (All naive cross section results are shown in appendix in Table 3). This shows a clear underestimation of the risk when ignoring the cumulative exposure, pointing to a strong HWE.

Figure 5 shows our adjusted regression models, disaggregated into annual basis. Compared to the baseline results (dashed line), we see that the risk decreases over time as the study population ages and the healthy survivors make up a larger share of the exposed population. While individual years illustrate the overall trend, there is a trend of reduced risk in later years. However, this should be compared with the HWE, as these later years include a smaller population of healthy survivors.

Discussion

Our findings reveal a significant increase in the risk of hospital-diagnosed back disorders with just 4 years of PJE over a 10-year period. This indicates a critical time window where the risk peaks, and subsequent exposure shows a decline, aligning with the HWE observed by Hartvigsen et al. [13]. It's plausible that younger or less experienced workers, tasked with the heaviest and most strenuous duties, contribute to the early rise in OR, as supported by our findings in Fig. 5. These OR values tend to decline in year-by-year adjusted models compared to the baseline model.

Consistent with a review by Burdorf [22] and a review reference document by Jahn et al. [23], our study identifies an increased risk of back disorders after PJE. Variations in study design and exposure measurements may explain differing estimates. Our longitudinal results differ from naive cross-sectional models, with cross-sectional studies often

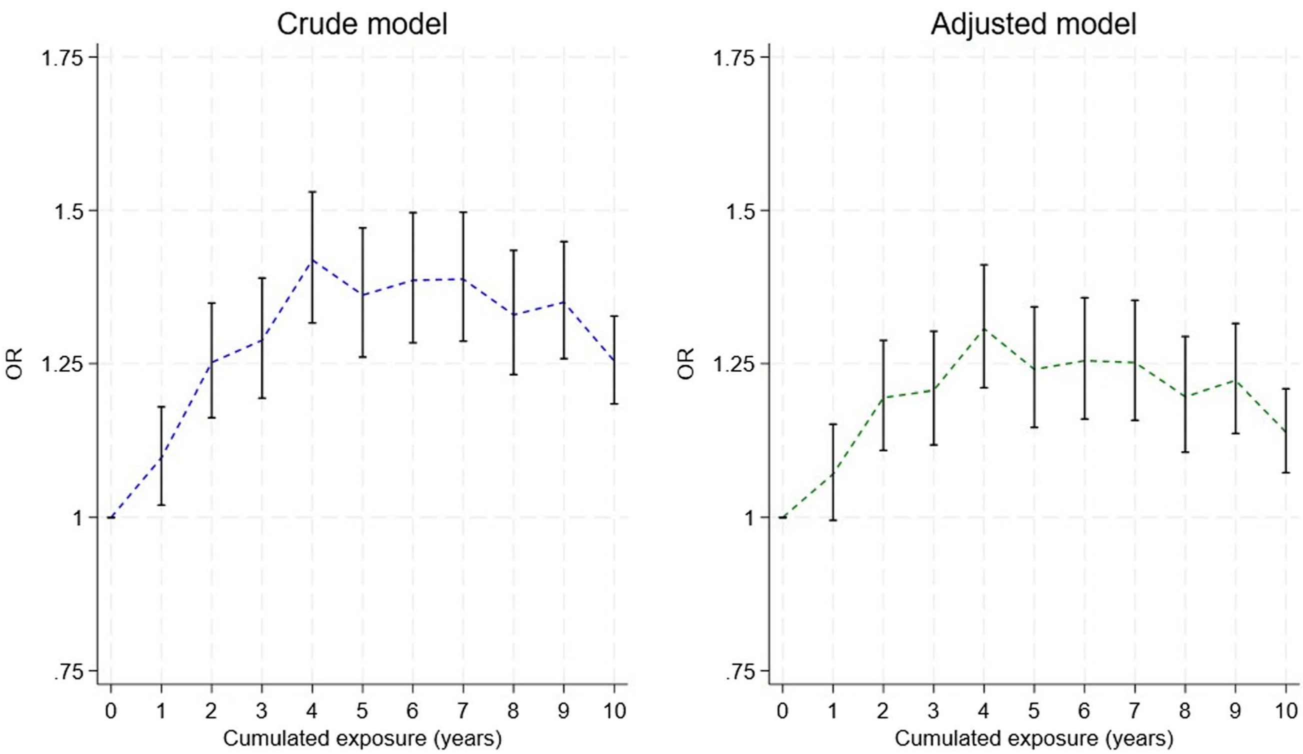
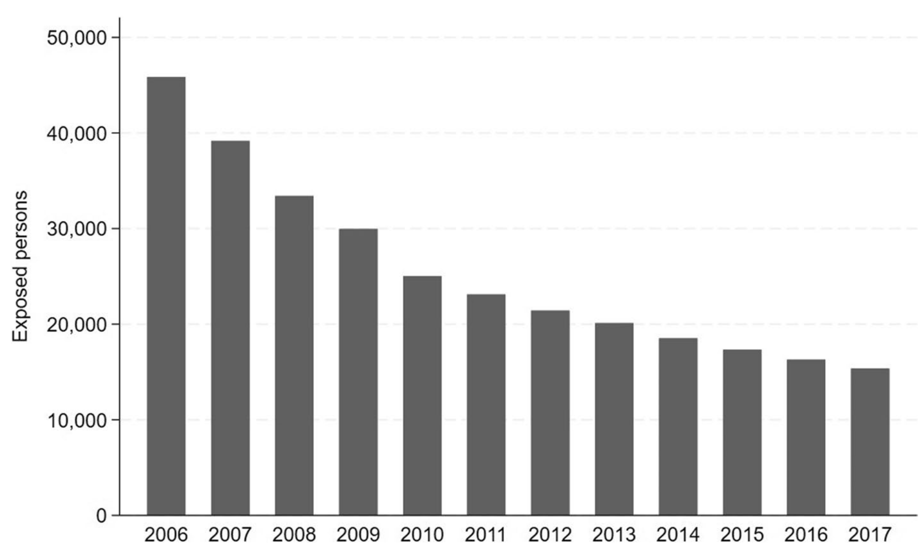


Fig. 2 OR of incident hospital-diagnosed back disorder in relation to the cumulated years of physical job exposure (also shown in Table 2 in the appendix)

Fig. 3 Healthy survivors. Note: The figure illustrates how the 48,000 individuals (app 37%) that are exposed to PJE in 2006 migrate away from exposed occupations



reporting lower OR due to the HWE, thus underestimating the actual risk and highlighting the need for more longitudinal studies.

Emphasizing our exclusive focus on hospital-diagnosed back disorders distinguishes our study from others relying predominantly on self-reported data, e.g. as the studies by Hoogendoorn et al. [9] and Cunningham et al. [10]. This difference in outcome measurement can contribute to higher OR values in the literature, as only the most severe cases of person with back disorders typically seek hospital care. Mortimer and Ahlberg [7] showed that the most decisive factors for seeking care due to back pain were high disability and pain intensity.

Our study's strengths include a large, representative cohort covering all individuals aged 18–21 in Denmark in 1996, extensive follow-up, high-quality longitudinal

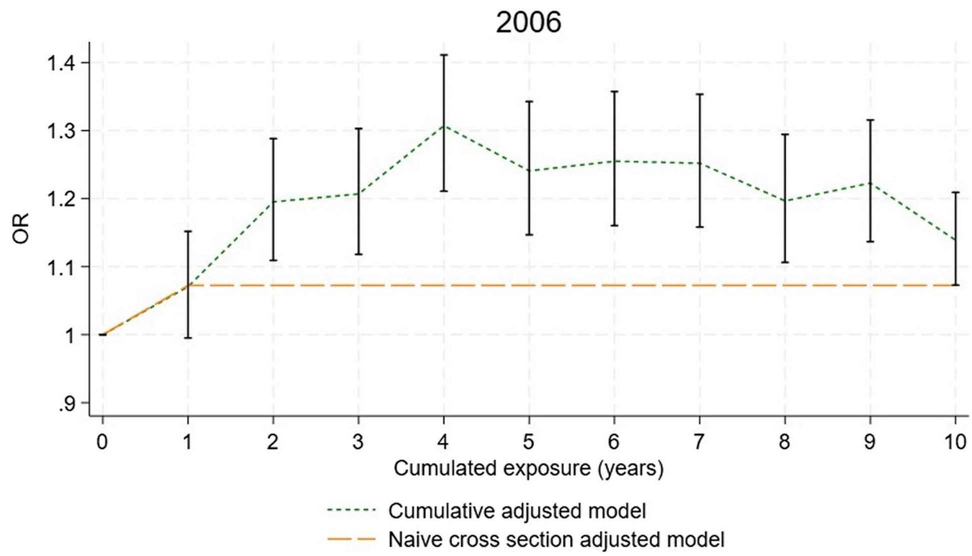


Fig. 4 Cumulative vs naive risk estimate

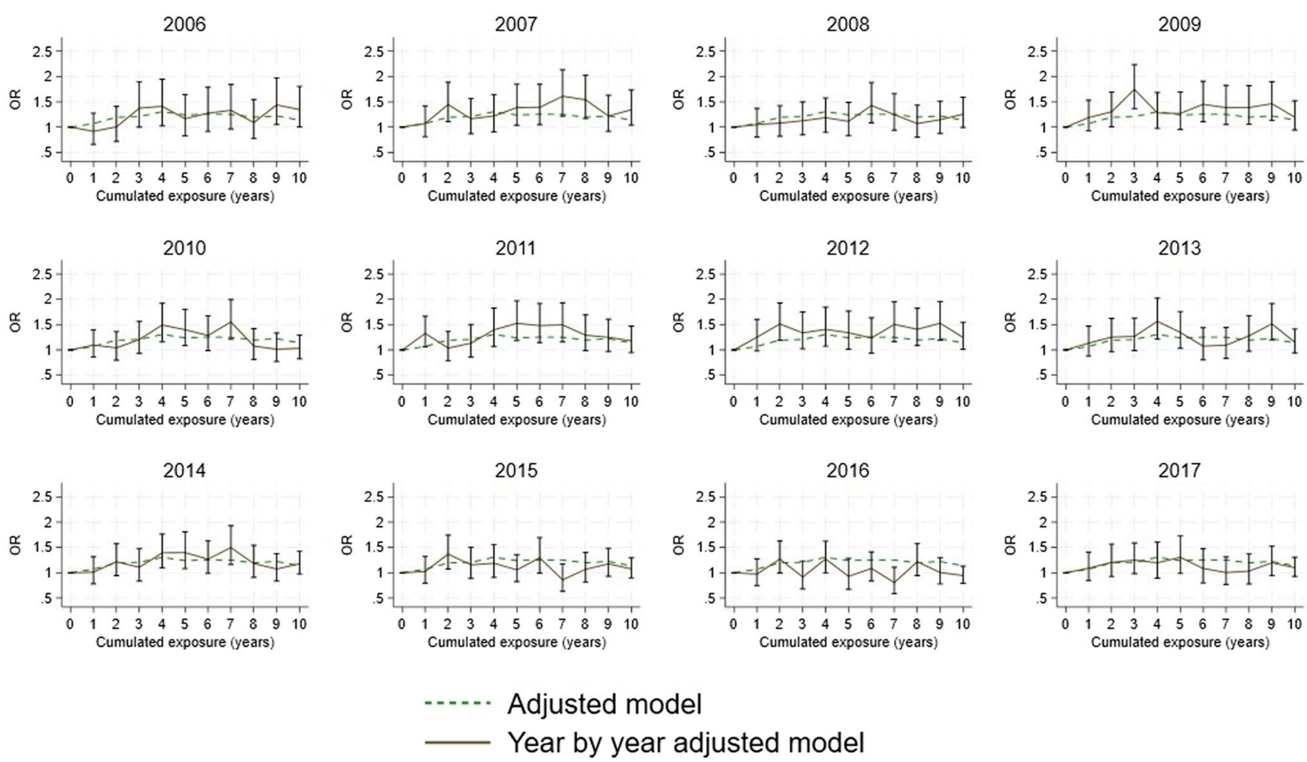


Fig. 5 Adjusted regression models disaggregated on an annual basis

register data, and a lower-body job exposure matrix (JEM) with good predictive validity for several outcomes [17, 18].

Study limitations include exposure misclassification, missing data on leisure time activities, and lifestyle factors. Exposure misclassification is a general limitation when using JEMs. The JEMs do not allow exposure at an individual level, and the exposure per definition does not differ within a job group. However, based on theories of Berkson and classical errors, group-based exposure assessment usually results in little to no decrease in the dose–response relationship if persons in the study can be allocated to exposure groups that differ with respect to their exposures [24, 25]. In the present study, the range of job-specific average exposure was relatively wide, which can be viewed as a minor issue. We partly addressed missing lifestyle factor data by controlling for higher education which is associated with lifestyle factors [26, 27].

This study focused solely on hospital-diagnosed back disorders, which can carry important policy implications as this approach may underestimate the overall burden of back disorders on public health and workforce productivity. Combining data from both hospitals and primary care settings in the future would provide a more comprehensive understanding of back health in the population. This would enable policy makers and medical practitioners to allocate resources more effectively, inform about preventive strategies, and targeted interventions to address the diverse spectrum of back disorders and their impact on individuals and society. Future studies examining specific diagnoses could likewise offer valuable insights for tailored policy development and guidelines, meeting the unique needs of individuals affected by different types of back disorders. Implementing such policy initiatives can optimize healthcare delivery and improve the overall well-being and productivity of individuals with back disorders.

In conclusion, our study demonstrates that after just 4 years of PJE an increase in the risk of hospital-diagnosed back disorders occurs. The longitudinal estimate is fourfold the estimate from a naive cross section model suggesting that cross-sectional studies strongly underestimate the risk of back disorders due to the healthy worker effect. Longitudinal approaches based on survey and register data show comparable point estimates, with nationwide registers providing greater precision. However, this is likely only the tip of the iceberg. If this pattern also extends to nonspecific and self-reported back issues, improving physically work conditions could have significant economic implications.

Appendix

See Tables 2, 3 and 4.

Table 2 OR of incident diagnosed back disorder in relation to the accumulated years of physical job exposure

Physical job exposure					
Cumulated exposure (years)	Number of exposed person-years	Crude model		Adjusted model[a]	
		OR	95% CI	OR	95% CI
1	110,349	1.10	1.02–1.18	1.07	1.00–1.15
2	92,052	1.25	1.16–1.35	1.20	1.10–1.29
3	84,443	1.29	1.19–1.39	1.21	1.12–1.30
4	78,168	1.42	1.32–1.53	1.31	1.21–1.41
5	75,995	1.36	1.26–1.47	1.24	1.15–1.34
6	75,229	1.39	1.28–1.50	1.26	1.16–1.35
7	77,995	1.39	1.29–1.50	1.25	1.16–1.35
8	80,049	1.33	1.32–1.44	1.20	1.11–1.29
9	93,990	1.35	1.26–1.45	1.22	1.14–1.32
10	177,146	1.25	1.19–1.33	1.14	1.07–1.21

[a]Adjusted for sex, age, higher education, region of residence (five categories), and start of follow-up year

Table 3 Naive cross section estimates year by year

Adjusted model[a]		
Year	OR	95% CI
2006	1.07	0.93–1.24
2007	1.26	1.10–1.44
2008	1.15	1.01–1.32
2009	1.10	0.96–1.25
2010	1.08	0.95–1.23
2011	1.15	1.01–1.30
2012	1.14	1.00–1.29
2013	0.04	0.92–1.18
2014	1.03	0.91–1.16
2015	1.06	0.94–1.19
2016	0.98	0.86–1.10
2017	1.09	0.96–1.22

[a]Adjusted for sex, age, higher education, region of residence (five categories), and year

Table 4 Full description of ICD-10 codes included

DM42	Spinal osteochondrosis
DM42.0	Juvenile osteochondrosis of spine
DM42.1	Adult osteochondrosis of spine
DM42.9	Spinal osteochondrosis, unspecified
DM43	**Other deforming dorsopathies**
DM43.0	Spondylolysis
DM43.1	Spondylolisthesis
DM43.2	Other fusion of spine
DM43.4	Other recurrent atlantoaxial subluxation
DM43.5	Other recurrent vertebral subluxation
DM43.6	Torticollis
DM43.8	Other specified deforming dorsopathies
DM43.9	Deforming dorsopathy, unspecified
DM47	**Spondylosis**
DM47.0	Anterior spinal and vertebral artery compression syndromes
DM47.1	Other spondylosis with myelopathy
DM47.2	Other spondylosis with radiculopathy
DM47.8	Other spondylosis
DM47.9	Spondylosis, unspecified
DM48	**Spinal stenosis**
DM48.1	Ankylosing hyperostosis [Forestier]
DM48.2	Kissing spine
DM48.4	Fatigue fracture of vertebra
DM48.5	Collapsed vertebra, not elsewhere classified
DM48.8	Other specified spondylopathies
DM48.9	Spondylopathy, unspecified
DM495	**Collapsed vertebra in diseases classified elsewhere**
DM50	**Cervical disc disorders**
DM50.0	Cervical disc disorder with myelopathy
DM50.1	Cervical disc disorder with radiculopathy
DM50.2	Other cervical disc displacement
DM50.3	Other cervical disc degeneration
DM50.8	Other cervical disc disorders
DM50.9	Cervical disc disorder, unspecified
DM51	**Other intervertebral disc disorders**
DM51.0	Lumbar and other intervertebral disc disorders with myelopathy
DM51.1	Lumbar and other intervertebral disc disorders with radiculopathy
DM51.2	Other specified intervertebral disc displacement
DM51.3	Other specified intervertebral disc degeneration
DM51.4	Schmorl nodes
DM51.8	Other specified intervertebral disc disorders
DM51.9	Intervertebral disc disorder, unspecified
DM53	**Other dorsopathies, not elsewhere classified**
DM53.0	Cervicocranial syndrome
DM53.1	Cervicobrachial syndrome
DM53.2	Spinal instabilities
DM53.3	Sacrococcygeal disorders, not elsewhere classified
DM53.8	Other specified dorsopathies
DM53.9	Dorsopathy, unspecified
DM54	**Dorsalgia**
DM54.0	Panniculitis affecting regions of neck and back
DM54.1	Radiculopathy

Table 4 (continued)

DM42	Spinal osteochondrosis
DM54.2	Cervicalgia
DM54.3	Sciatica
DM54.4	Lumbago with sciatica
DM54.5	Low back pain
DM54.6	Pain in thoracic spine
DM54.8	Other dorsalgia
DM54.9	Dorsalgia, unspecified
DM809C	**Unspecified osteoporosis with pathological fracture**
DM96	**Postprocedural musculoskeletal disorders, not elsewhere classified**
DM96.0	Pseudarthrosis after fusion or arthrodesis
DM96.1	Postlaminectomy syndrome, not elsewhere classified
DM96.5	Postradiation scoliosis
DM96.6	Fracture of bone following insertion of orthopaedic implant, joint prosthesis, or bone plate
DM96.8	Other postprocedural musculoskeletal disorders
DM96.9	Postprocedural musculoskeletal disorder, unspecified
DM99	**Biomechanical lesions, not elsewhere classified**
DM99.0	Segmental and somatic dysfunction
DM99.1	Subluxation complex (vertebral)
DM99.2	Subluxation stenosis of neural canal
DM99.5	Intervertebral disc stenosis of neural canal
DM99.6	Osseous and subluxation stenosis of intervertebral foramina
DM99.7	Connective tissue and disc stenosis of intervertebral foramina
DM99.8	Other biomechanical lesions
DM99.9	Biomechanical lesion, unspecified
DS13	**Dislocation, sprain and strain of joints and ligaments at neck level**
DS13.0	Traumatic rupture of cervical intervertebral disc
DS13.1	Dislocation of cervical vertebra
DS13.2	Dislocation of other and unspecified parts of neck
DS13.3	Multiple dislocations of neck
DS13.4	Sprain and strain of cervical spine
DS13.5	Sprain and strain of thyroid region
DS13.6	Sprain and strain of joints and ligaments of other and unspecified parts of neck

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Declarations

Conflict of interest No authors have any conflicts of interest to disclose. All authors have no financial or non-financial interests directly or indirectly related to this work.

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