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THE EFFECT OF ENTERPRISE SIZE ON THE RISK OF HOSPITAL TREATED INJURIES AMONG ALL MALE MANUAL CONSTRUCTION WORKERS IN DENMARK, 2000-2006

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ABSTRACT

Objectives
This study examines male manual construction workers in Denmark and the degree to which their employment in either micro, small or medium-sized enterprises bears an elevated risk of hospital treatment for injury compared to employment in large enterprises.

Methods
A nationwide register-based follow-up study was conducted among all male subjects registered as manual workers in the construction industry in Denmark from January, 2000 to December, 2006 when aged 21-59 years (n=183 738). The subjects were followed yearly through the national hospital patient register for injury in accordance to ICD-10 classification numbers S00-T98: "Injury, poisoning and certain other consequences of external causes" and linked to data about enterprise size. Enterprise sizes were related to a Danish context and defined as micro when 0-4 employees; small when 5-9 employees; medium when 10-19 employees; and large when at least 20 employees. The term 'enterprise' was defined as the local workplace unit, meaning each worker's workplace location from where orders are received. Poisson regression was used to assess the effect of enterprise size on injury rates for five year age groups.

Results
For all male manual construction workers in Denmark, the injury rates increased with enterprise size. With large enterprises as reference the age adjusted rate ratios were 0.90 (95% CI: 0.88 – 0.92) for micro, 0.94 (95% CI: 0.92 – 0.97) for small, and 0.96 (95% CI: 0.94 – 0.99) for medium-sized enterprises.

Conclusions
This study suggests that, in a Danish context, injury prevention efforts on the political front and in research should target construction workers in large rather than small enterprises.

INTRODUCTION

The improvement of safety and health in the construction industry remains a major global concern as it is one of the most hazardous industries to work in and at the same time a worldwide leading employer for both skilled and unskilled workers. Every five minutes a construction worker dies somewhere around the world [1], representing a massive loss of human lives due to the dangers inherent in construction work and the management hereof. Further, let alone for Europe, around 30 000 construction workers get so severely disabled every year that they can no longer work [2].

Even though it is widely recognised that a large number of the deaths and injuries in the construction industry are entirely preventable, a recent Cochrane review of intervention studies among construction workers shows that it has proved difficult to find effective and evidence-based ways to combat fatal and non-fatal injuries [3, 4]. This also holds true for intervention studies aimed at preventing construction workers´ large share (55%) of musculoskeletal disorders which consequently lead to non-fatal injuries in the USA [5]. Typically, construction projects are such complex hazardous systems and ever-changing in terms of task at hand, workforce and workplace condition that it makes it problematic for researchers to intervene with randomised controlled studies [6]. Yet there is an immense need for methodologically well-founded intervention research that can help reducing hazards and risks among construction workers.

In the designing process of intervention studies in the construction industry, it is important for safety experts to have a profound knowledge of the injury prevention potentials of the industry. Besides main risk factors such as behaviours of workers and work team; safety culture; organisational processes; and usage of work materials, technology and personal equipment, workplace size appears also to be a key issue in injury prevention. Several studies suggest that small and medium-sized enterprises (SMEs) are especially vulnerable workplaces in terms of guaranteeing a healthy and safe working environment [7] and that they carry an elevated injury risk [8-11].

Usually SMEs have fewer financial, human and technological resources available for organising safety and health precautions. This includes less ability to perform proactive or high-quality risk management [12-16]. In addition, the attitude of owners of SMEs to be more reluctant towards state regulation of employees´ health and safety and to underestimate risks may also compromise safety [17]. Thus, the overall impression of SMEs is that they seem less likely than large enterprises to provide a safer and healthier working environment. However, if you look at the statistical analyses of the relation between enterprise size and injury rates in construction, the picture is somewhat unclear.

McVittie *et al.* [18] investigated the effect of enterprise size on injury rates among construction workers in the Canadian province Ontario for the years 1988-1993. Based on records from the Workers' Compensation Board, this study showed that injury rates went down every single time the enterprise size increased. However, there was no control for occupational distribution within the enterprises that could explore if the lower injury rates among workers in the larger enterprises were due to more white-collar (office) workers performing less hazardous tasks. Also, the estimates may be biased by under-reporting since a Canadian study has shown that, overall seen, 40 % (48 % for Ontario) of those eligible for Workers Compensation report do not submit a claim [19].

Jeong [20] investigated the effect of enterprise size on injury rates among construction workers in South Korea for the years 1991-1994. Based on statistics from the South Korean Ministry of Labour of workers´ compensation claims and employers´ injury reports, this study showed that enterprises with fewer than 10 employees have a clearly higher injury rate and the largest enterprises with more than 1000 employees the lowest injury rate, but like in the study by McVittie *et al.*, there was no control for occupational distribution within the enterprises and the results may be biased by under-reporting, too.

Fabiano *et al.* [10] investigated the effect of enterprise size on injury rates in the Italian industry including construction for the years 1995-2000. Based on employers´ injury reports made to the Italian National Organization for the Labour Insurance, this study showed that enterprises with 1-30 workers had a nearly double as high injury rate compared to the largest enterprise size. However, despite the fact that Italian employers are strictly obliged to report injuries to the insurance and may face criminal charges if they do not, they also have to face possible legal proceeding if a reported injury involves more than 40 days absence from work. This may discourage employers from reporting injuries and add to the general problem with under-reporting.

Kines *et al.* [21] investigated the effect of enterprise size on injury rates due to elevation falls among construction workers in Denmark for the years 1993-1999. This study showed inconclusive results since no noticeable trend was found. As noted by the authors, the result was possibly biased due to an under-reporting of approximately 50 % of the injuries. Moreover, enterprise size was not given in 13 % of the reported injuries, and

there was no control for the occupational distribution within the enterprises. According to Danish national data, injury rates among blue-collar workers are on average twice as high as they are among white-collar workers [22].

Statistics from the European Commission, from year 2005, show a higher non-fatal injury incidence rate of around 6 500 per 100 000 construction workers in SMEs (1 to 249 employees) compared to an injury incidence rate of 4 700 per 100 000 construction workers in large enterprises (more than 250 employees)[2]. For fatalities in construction, the incidence rate is around 9 per 100 000 in SMEs while 5.5 for large enterprises [2].

The comparisons of SMEs and large enterprises, when based on the European enterprise categorizations, is, however, not very useful in a Danish context. In Denmark, a EU member state of 5.5 million inhabitants and with just 2 % of its enterprises employing more than 50 workers [23], the enterprise categorization differs from that of EU in the way that Danish enterprises are considered large when they employ more than 20 workers [24]. (Over the past few years, the Danish definition of a large enterprise has changed and now sets the minimum number of employees to either 20, 35 or 50). When looking at the Eurostat injury data for the relation between the smallest enterprise sizes, data do not indicate that injury rates decrease with enterprise size [2]. In fact, the reported injury rates among enterprises with 1-9 employees were lower than in enterprises with 10-49 employees in each of the studied calendar years (1996-2005). However, EU´s injury data could also be subject to under-reporting because data, in the case of Denmark (and UK and Ireland), are based on reports made by employers to the National Labour Inspectorate and not all employers file injury reports. The Danish National Working Environment Authority has assessed the degree of under-reporting of injuries to be approximately 50 % [25]

The question of whether small construction enterprises account for a higher injury risk cannot be answered satisfactorily with existing evidence. Partly because data in most of the studies may be influenced by biased under-reporting and may lead to conclusions of under- or overstated risks, and partly because most of the studies do not control for the occupational distribution within the enterprises which may lead to conclusions of white- and blue-collar work in construction being equally risky.

The primary aim of this study is to investigate the relation between enterprise size and injury rates in the Danish construction industry, on a register based data set that is free from reporting bias and conducted among manual (blue-collar) workers only. A conditional aim is to investigate if a change in Danish legislation, which was implemented from July 1, 2002, affected the injury rates among construction workers in enterprises with 5-9 employees. The change in legislation cancelled the requirement to have a safety organisation for Danish enterprises with 5 – 9 employees and may have resulted in a higher risk of injury in these enterprise sizes.

A secondary aim of this study is to estimate injury rate ratios in the occupational groups included in the analysis; bricklayers, carpenters, plumbers, electricians, painters, and unskilled construction workers. A special attention is given to the rates among bricklayers, carpenters and plumbers whose working environment we plan to investigate in a subsequent project funded by the same grant as the present study. The findings of this research can be used as valuable information for policy makers, safety researchers as well as construction contractors who are occupied with the development and implementation of ways to improve safety in the construction industry.

Note

Before we performed any of the statistical analyses, a statistical model was completely specified and published as an open access study protocol [26], thereby eliminating hindsight bias from the study.

MATERIALS AND METHODOLOGY

The study was designed as an observational analytical population study. The population consisted of all male manual construction workers in Denmark aged 21-59 years. It was a dynamic population, i.e. open for both entry and departure. The public registration of all local workplace units in Denmark was launched in 1999. In the present study, a person's work category during a certain calendar year was determined by his enterprise association according to the population census performed in the end of November the preceding year. The study period began January 1, 2000 with the first calendar-year in which data on enterprise size could be merged with hospital records, and ended December 31, 2006 with the year of the latest accessible statistical returns from Statistics Denmark by the time of finalizing the research design of the study (2009). Note: In our study protocol [26] it was erroneously stated that the study period would begin January 1, 1999.

The population was followed one year at a time for first hospital treated injury during the year. The injuries were diagnosed on the basis of ICD-10 classification numbers S00-T98: "Injury, poisoning and certain other consequences of external causes" [27]. Included in the study was the principal diagnosis as concluded either by

discharge from the hospital or by transfer to another hospital division. Hence, the principal diagnosis was the condition which best described the reason for the admission of the injured patient to the hospital for care.

Data sources and classifications

The Danish Occupational Hospitalisation Register (OHR) was used to identify injured individuals. Included in the OHR are all persons who have been a legal/registered inhabitant of Denmark, aged 20 or more, at one time or another since 1980. OHR consists of a record-linkage between three national registers: 1) the central person register, 2) the national hospital patient register, and 3) the employment classification module [28, 29].

The central person register contains information on gender, addresses, and dates of birth, death and migrations for everyone registered as living in Denmark sometime from 1968 to present.

The national hospital patient register contains data from all public hospitals in Denmark. Patient diagnoses have been coded according to the international classification of diseases version ten (ICD-10) since 1994. Since 1995, the register has covered all inpatients, outpatients, and emergency ward visits [30]. Relevant for the present study was that no private emergency wards existed in Denmark in the follow-up period, and that less than 1% of all planned surgery on in- and outpatients took place in private hospitals in the follow-up period [31].

The employment classification module contains annually registered information on a person's industry, occupation, and employment status from 1975 onwards [30]. For the time-period spanned by the present study, the industries were initially coded according to the 1993 and then to the 2003 version of the Danish Industrial Classification of All Economic Activities [32, 33]. These classification systems are national versions of the European Industrial Classification of All Economic Activities (NACE rev. 1). NACE rev.1 divides industries hierarchically into 17 level-1 sections identified by alphabetical letters A to U; 60 level-2 divisions identified by two-digit numerical codes (01 to 99); 222 level-3 groups identified by three-digit numerical codes (01.1 to 99.0), and 503 level-4 classes identified by four-digit numerical codes (01.11 to 99.00). In the present study only levels 1 and 2 were used; at level 1, the letter "F" refers to the construction industry and its level 2 number is "45".

The occupations in the employment classification module were coded according to DISCO-88 [34], which is a national version of the international standard classification of occupations (ISCO-88) [35]. DISCO-88 divides the occupations hierarchically into 10 major groups; 27 sub-major groups; 111 minor groups, and 372 unit groups. In the present study the major groups related to manual construction work were included in the study, that is belonging to group 7 "Craft and related trades workers"; group 8 "Plant and machinery operators and assemblers", and/or group 9 "Elementary occupations".

OHR-data of each injured individual was linked to the latest national statistical returns of workplace size and local workplace unit. The statistical returns are assessed by Statistics Denmark every year in week 48, i.e. the last week in November, and imply that the employment data about each injured individual in the population stem from the year before the hospital treatment of the injury. Data about workplace size identifies the number of employees in addition to the owner of the workplace. Data about workplace unit identifies the local workplace unit where the injured individual was mainly carrying out his job. The local workplace unit can be the exact same as the mother enterprise unit, or it can be a unit belonging to the mother enterprise, but with a different geographical location and therefore with a different unit number. If a person worked in more than one place, which is often the case for construction workers, the local workplace unit is taken to be the workplace from where instructions emanate, or from where the work is organised.

Records were linked by means of a unique personal identification number and are kept at Statistics Denmark. Researchers are authorized to use data with encrypted personal identification numbers, and it is secured so that no analyses identifying any person or enterprise can be transferred outside Statistics Denmark.

Study population

Inclusion criteria for the study population were:

- main employment in the construction industry (NACE code = '45');
- employment status as employee or self-employed, that is with the highest income as such during the year;
- job function as manual worker (DISCO-88 code = 7, 8 or 9);
- age from 21 to 59 years – the former time limit due to available OHR-data from the age of 20 and the first available enterprise size data from Statistics Denmark from year 2000 at age 21; the latter time limit due to the possibility of job release scheme from the age of 60;
- male worker – the women were left out of the study since they constitute less than four percent of the blue-collar workers of the Danish construction industry.

A person entered the population as soon as all of the above criteria were fulfilled, and departed whenever they were no longer met.

Statistical analyses

A person became a case once receiving a principal diagnosis in the ICD-10 interval S00-T98 (“injury, poisoning and certain other consequences of external causes”) according to the OHR. For any given calendar year, a person was censored at the time he became a case, emigrated or died. Time-dependent dummy variables were used to categorise the manual workers into micro enterprises (fewer than 5 employees), small enterprises (5-9 employees), medium-sized enterprises (10-19 employees), and large enterprises (20 or more employees).

The null hypothesis stating that “the injury rates among workers are independent of enterprise size” was tested. If the null hypothesis was rejected meaning that the observed injury rates most likely depend on enterprise size, a second null hypothesis would be tested. This second null hypothesis would test if “the injury rate ratio among workers in enterprises with 5-9 employees compared with other workers is independent of time period (January 1, 2000 – June 30, 2002 versus July 1, 2002 – December 31, 2005)”. By this, it would be tested if it can be assumed that the legislative change that took place in Denmark on 1 July, 2002, which cancelled the requirement of having a safety organisation in enterprises with 5-9 employees, did not have any effect on the injury rates among the workers in enterprises with 5-9 employees.

To deal with intra-enterprise correlations, a multi-level Poisson regression was used to model the outcome, where the enterprises were treated as the subjects while observations within the enterprises were treated as correlated repeated measurements.

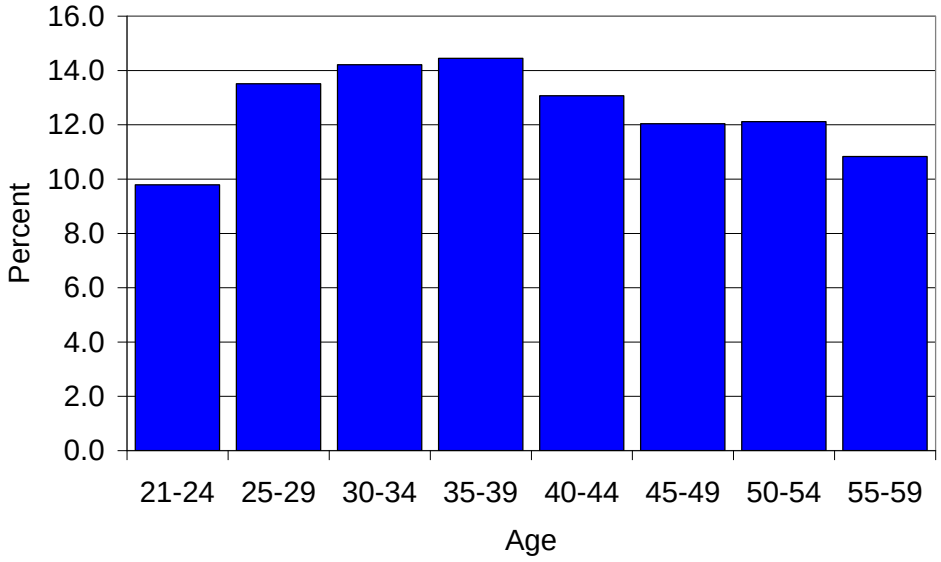
The analyses were controlled for age (five-year age groups), calendar year (as categorical variable) and occupation. Occupation unit groups were: Bricklayers and stonemasons (DISCO-88 = 7122); Carpenters and joiners (DISCO-88 = 7124); Plumbers and pipe fitters (DISCO-88 = 7136); Electricians (DISCO-88 = 7137); Painters and wall-paper workers (DISCO-88 = 7141); Unskilled manual workers in construction workers (DISCO-88 = 9313).

The analyses were performed by use of the GENMOD procedure in SAS version 9.1. Only main effects were considered. Initially, an exchangeable correlation structure (EXCH) was assumed. The co-variance estimation procedure did, however, not converge when this correlation structure was used, so we had to resort to the simpler independent structure (IND). The empiric standard error estimates were used. The significance level was set to 0.05.

RESULTS

194 109 persons fulfilled the inclusion criteria for at least one of the studied calendar years. 10 371 persons (5.3%) were excluded due to missing information about enterprise size. The remaining 183 738 were included in the analysis. The follow-up encompassed 653 525 person years, in which 100 534 cases were observed. On average, 20.5% of the workers were employed in micro enterprises, 16.0% were employed in small enterprises, 17.8% were employed in medium-sized enterprises and 45.7% were employed in large enterprises. The age distribution of the workers (five year age groups) is given in Figure 1.

Figure 1. *Age distribution among the included construction workers.*



Test of our first null-hypothesis

The first null hypothesis stating that "the injury rates among workers are independent of enterprise size" had to be rejected. The injury rates among the workers were not statistically independent of enterprise size ($P<0.0001$). The lowest rate was observed among workers in micro enterprises (fewer than 5 employees), and each increase in enterprise size category was followed by an increase in injury rate [RR=0.90 (95% CI: 0.88 – 0.92) to RR=0.96 (95% CI: 0.94 – 0.99)] (see table 1).

Table 1.
Injury rate ratios (calculated through poisson regression) among manual construction workers, by enterprise size.*

	Person Years	**Cases**	**Injury Rate Ratio**	**Confidence Interval (95 % CI)**
Micro (0-4 employees) vs. large (at least 20 employees)	134013	18072	0.90	0.88 - 0.92
Small (5-9 employees) vs. large	104334	16710	0.94	0.92 - 0.97
Medium-sized (10-19 employees) vs. large	116377	18732	0.96	0.94 – 0.99
Large (20 or more employees)	298800	47020	1.00	-

* The injury rate ratios were obtained by dividing rates (adjusted for age, calendar year and occupational distribution) among workers in the respective enterprise size categories with the rate among workers in large enterprises (the reference category).

Test of our second null-hypothesis

The second null hypothesis stating that "the injury rate ratio among workers in enterprises with 5-9 employees compared with other workers is independent of time period (January 1, 2000 – June 30, 2002 versus July 1, 2002 – December 31, 2005)" could not be rejected. We did not find any effect of the legislative change that took place in Denmark on 1 July, 2002, which cancelled the requirement of having a safety organisation in enterprises with 5 – 9 employees; the injury rate ratio among workers in this size category compared with other

workers was statistically independent of time period [RRR (relative rate ratio) = 1.02 (95% CI: 0.98 –1.05), (P = 0.418)]. With relative rate ratios (RRR) we mean the ratio of two rate ratios.

Injury rates in occupational groups

We found a significant association between type of occupation and injury rate (P < 0.0001). As mentioned in the introduction, we highlight the rates among bricklayers, carpenters and plumbers because their work environment will be explored in a later analysis. Compared with the average construction worker, the injury rates among bricklayers were significantly lower [RR= 0.82 (95% CI: 0.80 – 0.84)], whilst the rates among carpenters and plumbers were significantly higher [RR= 1.15 (95% CI: 1.13 – 1.17) and [RR= 1.17 (95% CI: 1.16 – 1.22), respectively]. The injury rate ratios of all analysed occupational groups are given in table 2.

Table 2.

Injury rate ratios (calculated through poisson regression) among manual construction workers,by type of occupation.*

	Person Years	**Cases**	**Injury Rate Ratio**	**Confidence Interval (95 % CI)**
Bricklayers and stonemasons vs. all other manual construction workers	65189	7796	0.82	0.80 - 0.84
Carpenters and joiners vs. all other manual construction workers	160997	27647	1.15	1.13 - 1.17
Plumbers and pipe fitters vs. all other manual construction workers	66864	12409	1.19	1.16 - 1.22
Electricians vs. all other manual construction workers	79317	11347	0.80	0.78 - 0.82
Painters and wall-paper workers vs. all other manual construction workers	46383	5400	0.80	0.77 - 0.82
Unskilled construction workers vs. all other manual construction workers	33731	5551	1.12	1.08 - 1.16

* The injury rate ratios were obtained by dividing rates (adjusted for age, calendar year and enterprise size distribution) among workers in the respective occupations with the rate among all other manual construction workers.

DISCUSSION

This study investigated all Danish men aged 21-59 years who were employed or self-employed as manual (blue-collar) construction workers some time during the time period 2000-2006 (n=183 738). The workers were followed up for hospital contacts due to injury and linked to prior-year information about occupational group and enterprise size. After control for age, calendar year and occupation, the analysis showed that construction workers in micro, small, and medium-sized enterprises had a lower injury rate than construction workers in large enterprises, and that the injury rates were steadily increasing with enterprise size. Construction workers in micro enterprises thus showed the lowest injury risk. One explanation for this difference in risk may be that construction workers in large enterprises presumably more often engage in building or construction projects of greater complexity where the degree of safety hazards is significantly higher than in smaller construction or building projects. In line with this assumption it has been shown that construction workers who worked with the construction of a large Danish high-level bridge (1988-1998) had an almost twice as high injury rate than averagely recorded for construction workers in Denmark [36].

Since the follow-up was done through registers and included the entire target population we were able to eliminate response and sampling, bias. Under-reporting in the construction industry is considered a serious problem and a recent study argues that particularly small construction enterprises (1-10 employees) fail to report

injuries to the authorities [37]. Another strength of this study is that we obtained a detailed insight into the variable enterprise size and were able to include in the analysis not just the level of mother plants (e.g. a company's head office) in the construction industry but the local workplace units, too. In this way we could distinguish between the enterprise size of mother plants and their workplace locations and hence detect the more accurate size of the workplace where the workers work on a daily basis or receive their daily orders from.

That the study subjects were not randomised into the various enterprise size categories is a limitation to this study; our analysis cannot differentiate between selection effects and effects that are due to the work environment. Another potential limitation is that the register does not differentiate between work-related and leisure time injuries. However, our study subjects form a rather homogenous occupational group and there are no obvious reasons to believe that their leisure time injury rates depend on enterprise size.

Substantial research has been carried out with the intention of reducing injury rates among various groups of construction workers. Among carpenters a lot of attention has been given to the reduction of back injuries [38, 39], knee injuries [40], and injuries due to falls [41-44]. Among plumbers, being struck by objects seems to be a common cause of injury [45]. Among bricklayers, risk of musculoskeletal injury due to back, neck, and shoulder problems is well discussed [46-48]. In this study we also compared injury rates among various occupations within the construction industry. We found that the injury rates among carpenters and plumbers were statistically significantly higher than those of bricklayers, painters, and electricians. Due to the high frequency of injuries these results, too, are of great practical significance. To give a concrete example, the injury rates among carpenters would decline by approximately 3000 injury related hospital contacts per year if their risk level were to be brought down to the level of bricklayers, electricians, and painters. If the same could be done for plumbers an additional reduction of approximately 4000 injury cases per year would be obtained. For Denmark, these are rather high numbers since alone the reported cases of work-related injuries to the National Working Environment Authority constitute 4000-6000 cases per year.

In conclusion, this study provides accurate estimates of the number of injuries that are linked to the Danish construction industry. Our results highlight the importance of viewing enterprise size and injury rates in its national business context. In Denmark, injury prevention efforts should be directed more towards the larger construction enterprises, rather than the smaller.

LIST OF ABBREVIATIONS

SMEs: Small and medium-sized enterprises: Firstly, the term "SME" contains micro, small as well as medium-sized enterprises. In a European context, SMEs are distinguished as: Micro enterprises with fewer than 10 employees, small enterprises with 10 to 49 employees, and medium-sized enterprises with 50 to 249 employees [16]. Secondly, in this study the distinction of the enterprise size-classes is based on the Danish business pattern: Micro enterprises include the self-employed and enterprises with fewer than 5 employees, small enterprises have 5 to 9 employees; medium-sized enterprises have 10 to 19 employees; and large enterprises employ at least 20 persons.

EU: The European Union. At present (2012), EU has 27 member states. By 2004, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia joined the EU. By 2007, Bulgaria and Romania joined the EU.

ICD-10: International Classification of Diseases version number 10. ICD-10 was endorsed by the Forty-third World Health Assembly in May 1990 and came into use in WHO Member States as from 1994.

OHR: The Danish Occupational Hospitalisation Register.

DISCO-88: National version of the international standard classification of occupations (ISCO-88).

NACE rev. 1: Statistical classification of economic activities in the European community from 1 January 1993. The word NACE is a French acronym for "Nomenclature generale des Activites economiques dans les Communautes europeennes", the first classification from 1970 covering the whole range of economic activity.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

BHP and HH designed the study and prepared the first draft of the manuscript. All authors contributed in a critical revision of the manuscript. All authors have given their final approval of the version submitted for publication.

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