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Mortality and morbidity among bridge and tunnel construction workers who worked long hours and long days constructing the Great Belt Fixed Link

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Objectives This study aimed at estimating the mortality and morbidity of hospital treatment among bridge and tunnel workers who worked round the clock, long hours, and long weeks to construct the Great Belt Fixed Link.
Methods A cohort of all Danish workers in the construction industry was followed for death and first hospitalization and outpatient or emergency ward treatment over 6 years. Standardized mortality and morbidity ratios (SMR) were calculated for selected diagnoses, and 5123 bridge and tunnel construction workers were compared with all 109 383 Danish construction workers.
Results The comparison showed an overall SMR of 124 with a 95% confidence interval (95% CI) of 97–155. For infectious diseases and intestinal infectious diseases, the corresponding values were 156 (95% CI 132–184) and 167 (95% CI 117–230), respectively. For diseases of the nervous system, it was 138 (95% CI 118–160), and including nerve, nerve root and plexus disorders it was 135 (95% CI 104–171), for instance, mononeuropathies of the upper limbs (SMR 136, 95% CI 101–180). The SMR was 139 (95% CI 126–153) for circulatory diseases, 157 (95% CI 130–189) for ischemic heart disease, 129 (95% CI 114–146) for diseases of the respiratory system, 124 (95% CI 114–135) for diseases of the digestive system, and 115 (95% CI 108–123) for diseases of the musculoskeletal system and connective tissue, including other intervertebral disc disorders (than cervical) (SMR 130, 95% CI 109–154).
Conclusions Bridge and tunnel workers who work round the clock, long hours, and long weeks have a mortality rate that is as high as that of other construction workers, and they are treated more often in hospitals.

Key terms cohort study; diseases of the circulatory system; diseases of the digestive system; diseases of the musculoskeletal system and connective tissue; diseases of the nervous system; diseases of the respiratory system; hospitalization; infectious and parasitic diseases.

The Great Belt Fixed Link consists of a suspension bridge for cars, a twin tunnel for trains, and two parallel low bridges and a partially artificial island (1). Since 1 June 1997, all train traffic between Zealand and the western part of Denmark has gone through the tunnel. This transition cut the travel time across the Great Belt from 1 hour to 7 minutes. The suspension bridge for road traffic opened 1 year later.

The construction work took place from 1989 to 1998 in a rural area where the workers were recruited for a limited time and, therefore, usually had their home far away from the construction sites. They lived either in temporary camps during the employment period, or they preferred to commute long distances. A later study suggested that commuters, on the average, slept 1 hour less than the other workers (1).

A pilot study suggested that exposures characteristic of a large-scale construction project may be a threat to the health of bridge construction workers (2). Such exposures include piece-rate pay systems, living in building-site camps, heavy work, bad weather (strong wind, heat, cold, snow, and rain), long hours, long spells of work, overtime, round the clock shifts, high risk of accidents, commuting long distances, unhealthy drinking and eating habits, and low family social support. However, in this retrospective study, we could not measure or differentiate the effects of each of these exposures. There were, for instance, hundreds of different agreements about workhours, but most of them had one thing in common (ie, the people worked long weeks, for instance, 60 or 84 hours and had long spells off duty). In the reference group of construction workers, the

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labor market agreements call for a 37-hour week and, for the most part, work during daytime. According to a survey from 1995, the construction industry had significantly fewer employees (7%) working 48 hours or more than in other industries (3). Moonlighting was, however, relatively common and probably not included in the answers.

A recent review (4) listed several health problems associated with overwork, but the health consequences of working long hours and long days intermittently with long weeks off duty are not known (5). A Japanese case-control study suggested that a combination of long workhours and insufficient sleep is strongly, positively associated with the risk of acute myocardial infarction (6). The workforce for the construction of the Great Belt Fixed Link was often recruited from other industries because of the many workers needed. Some of the workers were involved in both previous and later bridge construction projects and had worked for more than one contractor on various parts of the Great Belt Link project. Ørbæk et al (7) studied the pylon workers at the Øresund Belt Link. The workers had the same 84-hour workweek (12 hours/7days) as the pylon erectors in the Great Belt project. The research team found a disturbance of the sleep pattern causing lack of sleep as the workers only slept 75–85% of their needed sleep during the workweek. On the average, it took 3 days for the workers to recover after the workweek. However, the research team did not find any reduction in neurobehavioral test performance and cortisol responsiveness by the end of the workweek (8).

The hypotheses in the present study came from the following three sources: (i) a pilot study from 1997 (2), (ii) the literature on construction workers' health and safety, and (iii) clinical observations by the head of the emergency medical team. The available time for recovery was reduced for commuters who added extra hours of traveling to their long hours, and we hypothesized that the recovery time might be too short for the workers to fully recuperate from day to day. An important hypothesis was that working long hours and long days may cause fatigue that accumulated from day to day. In turn, this fatigue may aggravate or cause disease.

Study population and methods

Study population

Company personnel files were used to identify workers who had been employed by at least one of the major contractors involved in the Great Belt construction works before 1996 and were classified according to social status in the employment classification module (ECM). Altogether 5933 male workers were identified in the company files, but 810 of them could not be found in the national register. We found it likely that they were foreigners without a permanent address in Denmark as of 1 January 1996. As such, they were unlikely to be admitted to Danish hospitals. The remaining 5123 male workers were included in the study. We had information about periods of employment in the Great Belt project from the company files, but, because of the strict rules of confidentiality, we were not allowed to link that information to the other register data. The exposure time was therefore not quantified.

The standard group, all 109 383 male employees in the construction industry and between 20 and 59 years of age at baseline, was identified in the national ECM. Unemployed workers were excluded. Registers regarding payments to the supplementary labor market pension fund, employment files for public employees, registers of graduation from various educational institutions, including labor market education, were all used in the classification of each person. Fixed criteria were used to handle inconsistencies between various sources of information. The ECM contains information concerning socioeconomic status, occupation, and industry. It was used to identify those who, in 1995, had their main income coming from the construction industry.

The 5123 bridge and tunnel construction workers, as well as the 109 383 workers in the entire construction industry, were followed for overall mortality and discharges due to the selected diagnoses from 1996 to 2001 inclusive. The calculation of overall mortality was based on the registration of death in the CPR.

The cohort members were no longer at risk of being treated in a hospital in Denmark (censored) from the date of first emigration or from date of death, whichever came first. Inpatient treatment was assessed, together with outpatient treatment and emergency visit, whichever came first. Potentially work-related main codes in the international classification of diseases were selected together with specific diagnoses mentioned in the international literature concerning construction work. The selected discharge diagnoses are shown in table 1.

The key figures that had been involved in negotiating the agreements concerning workhours at the various sites were interviewed. The most common work schedule was 7 days with 12 hours each, 7 day off duty, 7 nights with 12 hours each, and 7 days off duty. Two years after the start of the West bridge site, the work schedule was changed to 5 days with 12 hours each, one weekend off duty, 5 nights of work, and 7 days off-duty. However, many worked overtime throughout the weekends. Part of the onsite construction work on the west bridge was done on a usual 37-hour agreement, but overtime was so common that it represented most of the earnings for the workers. The tunnel construction workers also had long hours around the clock, but their agreements had to be adjusted to the kind of construction work they did. Therefore, several hundred different agreements were negotiated. Due to technical problems with the machinery and due to two major accidents, a flooding of the tunnels and a fire in the tunnels, the work process had to be intensified much more than planned. Overtime and competition between the bore teams stepped up the work rate.

Table 1. Age and social class standardized morbidity and mortality ratios (SMR) for selected diagnoses among 5123 bridge construction workers followed for hospitalization and overall mortality from 1996 to 2001, the standard being all employed construction workers. (Exp = expected, 95% CI = 95% confidence interval)

Diagonsis [a]	Cases (N)	Exp (N)	SMR	95% CI
Certain infectious and parasitic diseases (A00-B99)	136	87.2	156	131.8–184.4
Intestinal infectious diseases (A00-A09)	37	22.2	167	117.4–229.9
Malignant neoplasms (C00-D48)	137	131.0	105	88.5–123.7
Malignant neoplasms of lip, oral cavity and pharynx (C00-C14)	5	4.4	112	36.4–262.3
Melanoma and other malignant neoplasms of skin (C43-C44)	9	8.0	112	51.4–213.2
Diseases of the nervous system (G00-G99)	166	120.5	138	118.3–160.4
Episodic and paroxysmal disorders (G40-G47)	66	51.8	127	98.5–162.0
Nerve, nerve root and plexus disorders (G50-G59)	67	49.7	135	104.4–171.1
Mononeuropathies of upper limb (G56)	50	36.7	136	101.1–179.5
Diseases of the circulatory system (I00-I99)	385	277.4	139	125.6–153.3
Ischemic heart diseases (I20-I25)	113	72.1	157	130.3–188.5
Acute myocardial infarction (I21)	44	30.2	146	105.8–195.6
Diseases of the respiratory system (J00-J99)	245	190.2	129	113.7–146.0
Acute upper respiratory infections (J00-J06)	26	19.9	131	85.5–191.9
Influenza and pneumonia (J10-J18)	51	40.9	125	92.9–164.1
Chronic lower respiratory disease (J40-J47)	56	42.3	132	100.0–171.9
Lung diseases due to external causes (J60-J70)	5	1.9	264	85.4–615.0
Diseases of the digestive system (K00-K93)	530	428.4	124	113.6–134.7
Peptic ulcer (K25-K27)	49	28.9	170	126.5–224.3
Gastric ulcer (K25)	20	12.0	167	102.0–257.9
Duodenal ulcer (K26)	27	15.0	180	118.6–261.8
Inguinal hernia (K40)	100	93.7	107	86.8–129.8
Alcoholic liver disease (K70)	10	7.4	136	65.3–250.2
Dermatitis and eczema (L20-L30)	18	16.7	108	63.7–169.9
Diseases of the musculoskeletal system and connective tissue (M00-M99)	901	784.4	115	107.6–122.6
Coxarthrosis (M16)	16	15.4	104	59.6–169.1
Arthrosis of the knee (M17)	47	40.3	117	85.6–154.9
Cervical disc disorders (M50)	23	18.0	128	81.0–191.8
Other intervertebral disc disorders (M51)	129	99.3	130	109.3–154.4
All cause mortality	75	60.7	124	97–155

[a] The code of the International Classification of Diseases and Related Health Problems (10th revision) follows the diagnosis in parentheses.

Analysis

The standardized mortality or morbidity ratio (SMR) was calculated by dividing the observed number by the expected number of deaths or hospitalizations, outpatient treatments, or emergency contacts in the follow-up period in a given occupation. The expected number was based on age- and social-class-specific incidence rates for all workers in the industry. The 95% confidence intervals (95% CI) were calculated on the assumption of a Poisson distribution. For observed numbers lower than 100, we used the exact confidence limits. Otherwise we used maximum likelihood estimates.

Results

The median period of employment was approximately 2 years, and it was longest for those employed first. In the 6-year follow-up period, 75 of the workers died. The age and social class standardized mortality for the workers, in comparison with employed male construction workers, was 124 and the 95% CI was 97–155.

The risk of infectious diseases, especially the risk of intestinal infectious diseases, was higher than for other construction workers (table 1). A major hypothesis behind the present study was an increased risk of ischemic heart disease. The results confirm this hypothesis. The SMR for circulatory diseases, especially ishemic heart disease was increased. Table 1 also shows high risks due to other selected diseases, for instance, diseases of the musculoskeletal system and connective tissue, including disc disorders.

Discussion

This study describes the mortality and morbidity of the Great Belt bridge and tunnel construction workers in comparison with all construction workers. Bridge and tunnel construction workers were more often treated in the hospital due to the following diseases: infectious and parasitic diseases, diseases of the nervous system, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system, and diseases of the musculoskeletal system and connective tissue.

We measured the incidence of selected diagnoses as follows. We counted discharges with the chosen diagnoses independent of whether they were due to hospitalization, emergency ward visits, or outpatient treatment.

Referral bias is often a major problem in hospital-based studies. It was, however, a methodological strength of the present study that all of the first hospital treatments in Denmark due to the selected diagnoses are included, treatment is free of charge, and the geographic distances are small. However, a few small private hospitals offer surgery without waiting time. These admissions and treatments are also included in the OHR, but some minor bias may have arisen from a segregated willingness and ability to pay for fast treatment. It was shown for ischemic heart disease that only lower-grade hospital staff had an excess admission rate due to referral bias (9). However, softer end points and emergency ward contacts and outpatient treatment may be more problematic. If there was any effect of the referral system, it should show up as a reduced risk among the bridge and tunnel construction workers because the treatment from the on-site first-aid nurse reduced the referrals to the hospital (10). The construction workers on the piece-rate system are very well paid and need to be mobile to perform their job. Therefore, they may choose surgery at private hospitals to shortcut waiting lists, but such surgery is also included in the patient register.

Building and construction workers are a selected group. The ganger chooses gang members able to work fast and effectively to increase the gang income under the gang piece-rate pay system. In general, active gang members are therefore in good health. Furthermore, Siebert et al (11) demonstrated a healthy worker survivor effect in the construction industry. In our study, we chose the construction industry as the reference group. It is therefore unlikely that we underestimated the risks because of these selection mechanisms. Dilution of the effects were, however, not unlikely to be introduced by workers with a short employment period, and it was a drawback of our design that we could not quantify the exposures.

It has been shown that building and construction work is associated with excess risks of diseases of the musculoskeletal system and connective tissue, including prolapsed lumbar discs (12), and coxarthrosis (13, 14). It is, therefore, remarkable that the tunnel and bridge workers at the Great Belt had an excess risk of other (than cervical) lumbar disc disorders, even when compared with all construction workers.

Researchers from the National Institute for Occupational Safety and Health in the United States reviewed existing English language databases for information concerning exposures, work-related health, and the safety of construction workers (15). They concluded that the literature reported that construction workers have an increased risk for mesothelioma, on-the-job trauma, musculoskeletal injury, and dermatitis. They found that the risks for all-cause mortality, cirrhoses, cerebrovascular disease, chronic obstructive pulmonary disease, ischemic heart disease, and leukemia are less clear. In Denmark, construction supervisors had an increased risk of ischemic heart disease, but, in general, construction workers have an average or low risk in three European countries (16).

According to a recent Nordic study, the standardized incidence ratio (SIR) for cancer of the lip was statistically increased at a 95% level among other construction workers (than those with a specific occupation) in Denmark (SIR 194), Norway (SIR 160), and Sweden (SIR 159) (17). Other studies have shown that occupational exposure to sunlight is associated with cancer of the lip and skin (18). We found the same tendency, but the result was based on only five cases.

In the present study, we found an excess risk among the tunnel and bridge construction workers for circulatory diseases including ischemic heart disease and especially myocardial infarction. The work conditions were, in some respects, different for the bridge and tunnel workers in our study when compared with those of construction workers in general. Many of them lived in building camps, and they all worked long hours during long weeks. They may be comparable with workers in a Japanese case-control study suggesting that a combination of long working hours and insufficient sleep is strongly, positively related to the risk of acute myocardial infarction (6). An important difference is, however, that the bridge and tunnel workers also had long periods off-duty. Some may use it for recovery, others for another job or moonlighting. Unfortunately there is no way to measure these additional burdens retrospectively. The commuters who traveled long distances were left with too short a time to unwind and sleep. Many worked nights and shifts, shown to be risk factors for myocardial infarction (19, 20) and peptic ulcer (21). Recently, an unfulfilled need for recovery was shown to be a strong predictor of cardiovascular disease (22), and fatigue is much more prevalent among shift workers than among day workers (23).

Kang et al (24) found 915 cases of inguinal hernia among construction workers in a large-scale cross-sectional study in the United States and a relative risk of 2.34 (95% CI 1.94–2.74). An increased risk of being treated for inguinal hernia was formerly found among occupational groups performing hard physical labor (25). The tunnels and bridge construction workers had the same risk as other construction workers. The high risk of being admitted to the hospital due to influenza or pneumonia is not surprising since many of the tunnel and bridge workers live close together and are exposed to all kinds of weather conditions and exhaustion from working long hours round the clock.

In conclusion, we found that bridge and tunnel workers who ever worked round the clock, long hours, and long weeks had as high a mortality as other construction workers and were treated more often in hospitals due to infectious and parasitic diseases, diseases of the nervous system, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system, and diseases of the musculoskeletal system and connective tissue.

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References

1. Tüchsen F, Hannerz H. Building camps and work related injuries. Occup Environ Med 2004;61:370–1.
2. El-Salanti N, Brendstrup T, Hasle P, Jespersen L, Nielsen H, Fløe T. Psykosociale og helbredsmæssige forhold i camps: forundersøgelse [Psychosocial and health issues in building site camps: pilot study.]. København: Øresundskonsortiet/CASA; 1997.
3. Tüchsen F, Bøggild H, Burr H, Villadsen E. Arbejdstid [Working hours]. Copenhagen: National Institute of Occupational Health; 2002;
4. van der Hulst M. Long workhours and health [review]. Scand J Work Environ Health 2003;29(3):171–88.
5. Smith L, Folkard S, Tucker P, Macdonald I. Work shift duration: a review comparing eight hour and 12 hour shift systems. Occup Environ Med 1998;55:217–29.
6. Liu Y, Tanaka H. Overtime work, insufficient sleep, and risk of non-fatal acute myocardial infarction in Japanese men. Occup Environ Med 2002;59:447–51.
7. Ørbæk P, Kecklund G, Seger L, Åkerstedt T. Arbetsvecka på 84 timmar: trötthet, sömnmönster och stressreaktioner [Working hours of 84 h: tiredness, sleep pattern and stress reactions]. Lund, Stockholm: University of Lund and Institute of psychosocial medicine, Karolinska Institute; 2000.
8. Persson R, Ørbæk P, Ursin H, Kecklund G, Österberg K, Åkerstedt T. Effects of the implementation of an 84-hour workweek on neurobehavioral test performance and cortisol responsiveness during testing. Scand J Work Environ Health 2003;29(4):261–9.
9. Tüchsen F, Andersen O, Olsen J. Referral bias among health workers in studies using hospitalization as a proxy measure of the underlying incidence rate. J Clin Epidemiol 1996;49:791–4.
10. Spangenberg S, Mikkelsen KL, Kines P, Dyreborg J. Efficiency in reducing lost-time injuries of a nurse-based and the first-aid-based on-site medical facility. Scand J Work Environ Health 2005;31 suppl 2:104–9.
11. Siebert U, Rothenbacher D, Daniel U, Brenner H. Demonstration of the healthy worker survivor effect in a cohort of workers in the construction industry. Occup Environ Med 2001;58:774–9.
12. Jensen MV, Tüchsen F. Erhverv og diskusprolaps i lænden [Occupation and lumber disc prolapse]. Ugeskr Laeger 1995;157:1519–23.
13. Cooper C, Campbell L, Byng P, Croft P, Coggon D. Occupational activity and the risk of hip ostearthritis. Ann Rheum Dis 2002;55:680–2.
14. Schouten JSAG, de Bie RA, Swaen G. An update on the relationship between occupational factors and ostearthritis of the hip and knee. Curr Opin Rheumatol 2000;14:89–92.
15. Burkhart G, Schulte PA, Robinson C, Sieber WK, Vossenas P, Ringen K. Job tasks, potential exposures, and health risks of laborers employed in the construction industry. Am J Ind Med 1993;24:413–25.
16. Tüchsen F, Andersen O, Costa G, Filakti H, Marmot MG. Occupation and ischemic heart disease in the European Community: a comparative study of occupations at potential high risk. Am J Ind Med 1996;30:407–14.
17. Andersen A, Barlow L, Engeland A, Kjærheim K, Lynge E, Pukkala E. Work-related cancer in the Nordic countries. Scand J Work Environ Health 1999;25 suppl 2:1–116.
18. Håkansson N, Floderus B, Gustavsson P, Feychting M, Hallin N. Occupational sunlight exposure and cancer incidence among Swedish construction workers. Epidemiology 2001;12:552–7.
19. Bøggild H Shift work and heart disease: epidemiological and risk factor aspects [dissertation]. Aarhus (Sweden): Aarhus University, Faculty of Health Sciences; 2000. p 1–72.
20. Bøggild H, Knutsson A. Shift work, risk factors and cardiovascular disease [review]. Scand J Work Environ Health 1999;25(2):85–99.
21. Tüchsen F, Jeppesen HJ, Bach E. Employment status, non-daytime work and gastric ulcer in men. Int J Epidemiol 1993;23:365–70.
22. van Amelsvoort LG, Kant IJ, Bultmann U, Swaen GM. Need for recovery after work and the subsequent risk of cardiovascular disease in a working population. Occup Environ Med 2003;60 Suppl 1:i83-i87.
23. Jansen NW, van Amelsvoort LG, Kristensen TS, van den Brandt PA, Kant IJ. Work schedules and fatigue: a prospective cohort study. Occup Environ Med 2003;60 suppl 1:i47-i53.
24. Kang SK, Burnett CA, Freund E, Sestito J. Hernia: is it a work-related condition? Am J Ind Med 1999;36:638–44.
25. Tüchsen F, Bach E, Andersen O, Jørgensen J. Erhverv og hospitalsindlæggelse 1981–84: alle indlæggelser uanset diagnose [Occupation and hospitalization 1981–84: all diagnosis]. Copenhagen: Arbejdsmiljoefondet/Arbejdstilsynet/Arbejdsmiljoeinstituttet; 1989.