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Shift work and risk of occupational, transport and leisure-time injury. A register-based case-crossover study of Danish hospital workers

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ABSTRACT

Introduction: Shift work has been associated with sleepiness. Sleepiness from shift work may increase the risk of occupational injuries, but could also continue outside of work and increase risk of injury during commuting and leisure time. In this study, we assessed the associations between evening shifts, night shifts and quick returns, and risk of occupational, transport and leisure-time injuries.

Material and method: We used a case-crossover design to compare characteristics of the shift right before an injury with shifts in previous control periods (i.e. without an injury) within the same individual. Shift information was derived from the Danish Working Hour Database (DWHD) and linked to information on injuries from The National Patient Register. The study populations included a total of 13 337 occupational injuries, 2722 transport injuries and 9768 leisure-time injuries. Data were analysed by conditional logistic regression.

Results: In the adjusted analyses, the odds of an occupational injury were higher during evening compared with day shifts (OR 1.54, 95%CI 1.43–1.66) and quick returns compared with regular returns (OR 1.26, 95%CI 1.10–1.44). No higher odds of a leisure-time injury or leisure time transport injury were observed after evening shift or night shifts vs. day shifts, or quick returns vs. regular returns.

Conclusion: Our findings support the evidence of a higher risk of occupational injuries during evening shifts and after quick returns. Findings on leisure-time transport and commuting injuries were inconclusive, while we found no support for a higher risk of injury during leisure-time after evening shifts, night shifts or quick returns.

1. Introduction

Work outside regular day time (shift work) is common (Rajaratnam and Arendt, 2001). Of the workforce in Europe around 19% report having night work (≥ 2 h of work between 22:00–05:00) at least once per month (Sixth European Working Conditions Survey – Overview Report, 2017); 23% reported having less than 11 h between shifts at least once per month (Sixth European Working Conditions Survey – Overview Report, 2017). Shift work has been linked to reduced sleep duration (Kecklund and Axelsson, 2016; Perez-Olmos and Ibanez-Pinilla, 2014; Sallinen and Kecklund, 2010) and sleepiness (Åkerstedt, 1988; Härmä et al., 2002; Martikainen et al., 1998; Kazemi et al., 2016), which can cause poorer cognitive performance (Perez-Olmos and Ibanez-Pinilla, 2014; Kazemi et al., 2016; Goel et al., 2009; Pilcher and Huffcutt, 1996). This may increase the risk of injury as previous studies have linked reduced sleep duration (Uehli et al., 2014; Pereira et al., 2016), sleep difficulty (Uehli et al., 2014; Åkerstedt et al., 2002; Salminen et al., 2010) and sleepiness (Connor et al., 2002; Robb et al., 2008; Åkerstedt, 2000) to injuries (Uehli et al., 2014; Pereira et al., 2016; Åkerstedt et al., 2002; Salminen et al., 2010; Connor et al., 2002; Robb et al., 2008; Åkerstedt, 2000). Thus, sleepiness may be a mechanism linking shift work to injury and persist until recovery is achieved. However, sleepiness from shift work may not only affect risk of injury during work, but sleepiness could also continue outside of work and increase the risk of injury during commuting and leisure time after a work shift.

Most previous studies on shift work and injury have focused on occupational injuries (Violanti et al., 2012; Stimpfel et al., 2015; Dembe et al., 2006; de Castro et al., 2010; Trinkoff et al., 2007; Fischer et al., 2017; MacDonald et al., 1997; Hopcia et al., 2012; Vedaa et al., 2019) or transport injuries (Chiron et al., 2008; Steele et al., 1999; Stutts et al.,

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2003). A few studies have included all type of injuries (both at work and outside of work) when examining the risk of injury after shift work (Larsen et al., 2017; Nielsen et al., 2018; Chiu and Tsai, 2013). However, we have not identified any studies on shift work and leisure-time injuries. Specific characteristics of shift work have been linked to higher risk of occupational injury, e.g. shift type (Violanti et al., 2012; Dembe et al., 2006; Fischer et al., 2017) and quick returns (Trinkoff et al., 2007; MacDonald et al., 1997; Vedaa et al., 2019). The literature on shift work and transport injuries is limited. Compared with day shifts, some studies, including one on healthcare workers, point towards a higher risk of commuting injuries after night shifts (Steele et al., 1999; Stutts et al., 2003), while in a large follow-up study on employees in the energy sector, no differences were found (Chiron et al., 2008).

In general, previous studies on working hours and injuries have used self-reported data and a rough measure of exposure, which can result in information bias. Also, a between-worker comparison is often made, which can give rise to confounding from lack of exchangeability between exposure groups (Nielsen et al., 2018). By using a case-crossover design it is possible to handle differences between employees by self-matching, and it has been suggested as a useful design to study work factors and acute outcomes, such as occupational injuries (Maclure and Mittleman, 2000; Sorock et al., 2001; Mittleman and Mostofsky, 2014).

In this paper, we aim to assess how shift work characteristics affect the risk of occupational, transport and leisure-time injuries. In order to study this aim, we used a case-crossover design and register data on both exposure and outcome, to investigate if shift type (evening and night shift) and quick returns are associated with occupational, transport and leisure-time injuries.

2. Materials and method

2.1. Design

A multiple interval case-crossover design (Mittleman and Mostofsky, 2014) was applied with use of data from the Danish Working Hour Database (DWHD) outlining working hour arrangements linked to data from The Danish National Patient Register on injuries. We studied three separate outcomes: occupational, transport and leisure-time injuries. A key advantage of the case-crossover design is that time-invariant confounding is eliminated by self-matching. Self-matching implies that each case acts as its own control in different time periods (Maclure and Mittleman, 2000; Sorock et al., 2001; Mittleman and Mostofsky, 2014). Thus, only employees with an injury are included. A previous study using the DWHD showed highest risk of injury on the day and the day after a quick return (Nielsen et al., 2019). Therefore the case period was defined as the recent 48 h leading up to the registration of an injury at an emergency department. We used the unidirectional approach, where all control periods occurred before the case period, consistent with Vegso et al. (2007), as an injury may alter an employee's risk behaviour (Vegso et al., 2007). Control periods were matched to the case period by clock time and weekday, to adjust for differences across days of the week. Thus, for each case period we selected all (up to five) 48-h control periods occurring from 4 to 8 weeks before the injury. We selected control periods close in time to limit the risk of confounding from changes in e.g. age, season and organizational factors (e.g. same job, department and unit) (see Fig. 1).

2.2. Case selection

DWHD holds information on all employees in the five Regions, including all public hospitals and some administrative workers from 2007 to currently 2015 (Garde et al., 2018). In this study, all employees in DWHD between 2008 and 2015, who had an injury, were between 18 and 65 years old, and had worked at least one shift of ≥3 h were included. Employees were excluded if they had an injury within 1 year prior to entrance in DWHD, were new in job (employees registered in the DWHD < 100 days before the injury) or had not worked a shift in both the case and at least one control period. We only included each employee's first injury to avoid dependence between recurrent injuries in an individual (Vinson et al., 2003). We identified 13 337employees with an occupational injury, 2722 employees with a transport injury and 9768 employees with a leisure-time injury (Fig. 2).

2.3. Exposure

DWHD is based on payroll information and includes starting and ending times for each shift. Shifts separated by less than 1 h were combined into one shift and on-call shifts were excluded. Exposures were assessed based on the *most recent shift* within 48 h prior to the clock time of the injury registration at the emergency department on case and control days. Selection of the most recent shift depended on the type of injury. Occupational injuries are injuries occurring during work and therefore, the time of registration at the emergency department could be during a shift or shortly after a shift. For transport and leisure-time injuries, we selected only shifts that ended prior to the time of injury registration.

We assessed the following work shift exposures: (1) Shift type: Shifts were classified as day shifts (≥3 h between 08:00 and 13:59), evening shifts (≥3 h between 16:00 and 21:59) and night shifts (≥3 h between 00:00 and 05:59). If a shift covered more than one shift type (e.g. day and evening shift) it was excluded to avoid a mix of effects from long shifts covering two or more shift definitions. (2) Quick returns: categorized as quick returns (≤11 h) and regular returns (12–17 h) from end of last shift to start of next shift.

2.4. Injuries

Injuries were identified in the National Patient Register, which provide information on all patients registered at all Danish hospitals (Lynge et al., 2011). Hospitals are required to state the activity at time of injury (e.g. paid work, transport during leisure-time or sport and exercise) for all patients who contact the hospitals due to an accident (The Danish Health Data Authority, 2018). Besides the mandatory registration of type of injury, some injuries are subcategorized (e.g. injury during service activity, commuting or cooking). The time of the injury was not available in the register. Instead we used the clock time of the hospital contact. We linked data from the DWHD to the National Patient Register by the Danish personal identification number (Pedersen et al., 2006). All injuries from 2008 with a registration of the activity at the time of the injury (Danish NOMESKO codes: EUA (The Danish Health Data Authority, 2018) were included. Occupational injuries included 'paid work' (99%) and 'transportation as paid work' (< 1%). Transport injuries included 'transport during leisure-time' (100%). Injuries during commuting were identified among the 22% of transport injuries with sub-categories. Leisure-time injuries consisted of 'Domestic activity and unpaid work' (30%), 'Sport and exercise' (16%), 'Play and other leisure' (18%), 'Vital activity' (e.g. sleep) (11%) and 'Other Activity' (25%).

2.5. Statistical analysis

This study used a case-crossover design, which is a type of fixed effects model (Allison and Christakis, 2006). Only employees with a change in exposure between the case and control period (discordant pair) contribute to the analysis (Maclure and Mittleman, 2000; Mittleman and Mostofsky, 2014). Discordant *exposure pairs* were calculated as the total number of pairs where employees had respectively evening shift, night shift or quick return in the case period and reference (day shift or regular return respectively) during the control period. Discordant *reference pairs* were calculated as the number of pairs where the employee was assigned to the reference group in the case period and as exposed to evening shift, night shift or quick return in the control period. Also, the number of employees with at least one discordant pair was calculated.

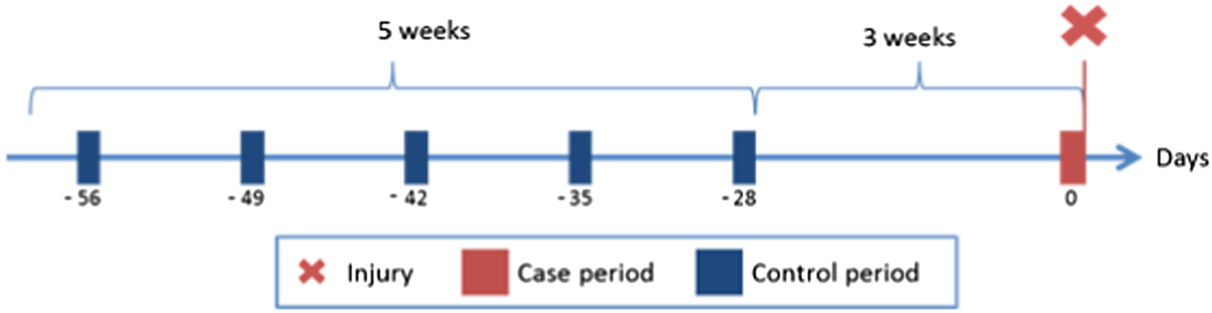

Fig. 1. Selection of case and control periods in the case-crossover design. The case period (red box) covers the 48 h leading up to the time of injury registration at the emergency department (red X). Five 48 h control periods (blue boxes) were selected on the same weekday 4 to 8 weeks prior to the injury registration. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

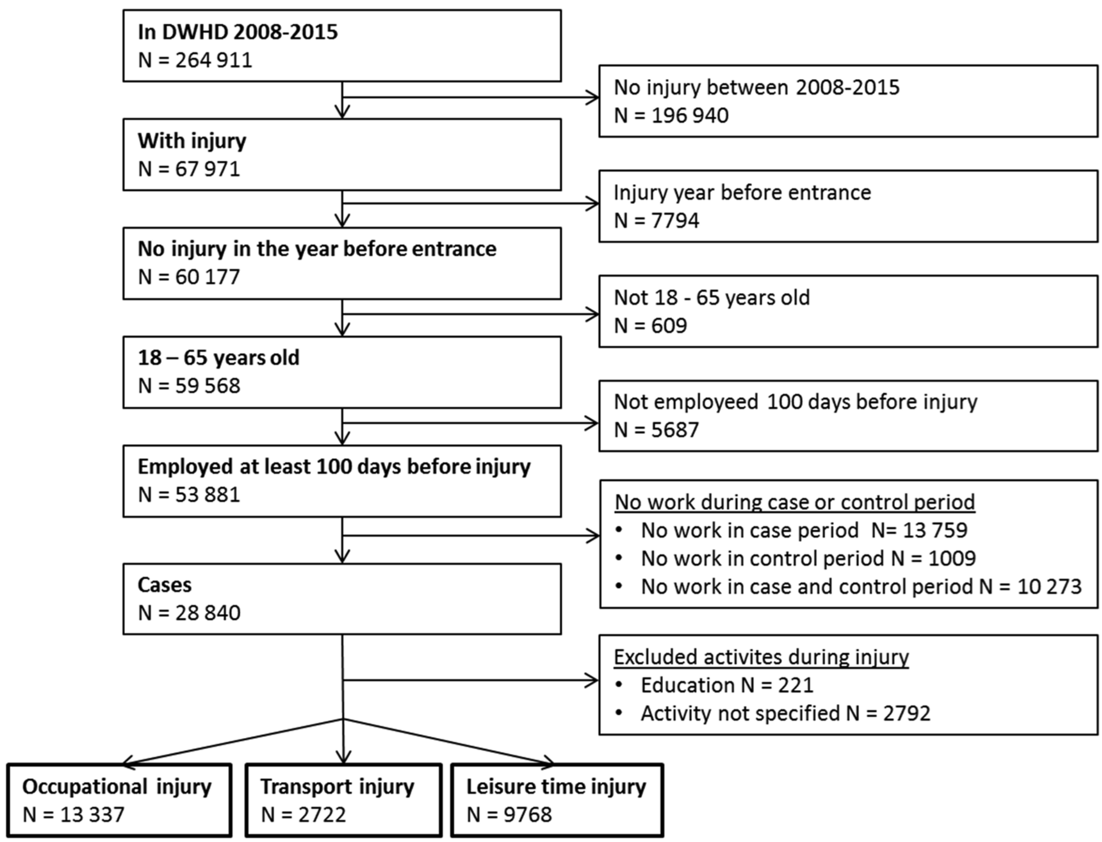

Fig. 2. Flow chart of the three study populations of employees with an occupational, a transport and a leisure-time injury.

The case-crossover matched-pair interval approach was used to compare each employee's exposures in the case period with exposures in the control periods. Analyses were performed separately for each outcome (occupational injuries, transport injuries and leisure-time injuries) using conditional logistic regression with the employee used as strata. Odds ratios (OR) were calculated with 95% confidence Intervals (95%CI). All analyses were conducted in SAS 9.4 (SAS Institute, Cary NC, USA) using proc PHREG to perform conditional logistic regression, in accordance with previous described techniques (Wang et al., 2011; SAS Institute Inc, 2018).

By using the case-crossover design results were adjusted for all time-invariant confounding, both measured and unmeasured, as each person is its own control (Mittleman and Mostofsky, 2014). Results were presented in a crude model (with no adjustment) and an adjusted model. The adjusted model included weekly working hours (working hours in the 7 days before the shift, used continuously) and short time between shifts in the analysis of evening and night shifts, and shift type in analysis of quick returns.

Transport injuries included commuting injuries and other transport injuries during leisure-time. Risk of injury could be higher during commuting right after certain shift work characteristics, than during later leisure-time transport. Thus, to examine if the risk of injury after certain shift work characteristics were similar for commuting injuries and transport injuries, we carried out a sensitivity analysis restricted to transport injuries specified as commuting injuries (N = 204).

Additional sensitivity analyses were performed of: (1) shift definitions without the 3 h restriction, (2) using 24 h case and control period instead of 48 h and (3) adjusting results for the shift type (day, evening, night or none) prior to the exposure shift within the 48 h window.

3. Results

Table 1 presents characteristics of the study populations. The distributions of men and women were similar across the three populations, with the majority being women. However, employees with an

Table 1
Characteristics of employees in case period (at time of injury).

Injuries	Occupational n = 13 337		Transport n = 2722		Leisure-time n = 9768	
	N	%	N	%	N	%
Age, year old						
18–24	2887	21.7	475	17.5	1485	15.2
25–34	3800	28.5	678	24.9	2314	23.7
35–44	3147	23.6	709	26.1	2555	26.2
45–54	2890	21.7	688	25.3	2720	27.9
55–65	613	4.6	172	6.3	694	7.1
Sex						
Women	10 713	80.3	2142	78.7	7685	78.7
Occupation						
Administrative work	708	5.3	668	24.6	2471	25.4
Patient contact	10 209	76.6	1643	60.6	5711	58.6
Technical staff	2411	18.1	402	14.8	1561	16.0
Missing	9		9		25	

Occupation is based on DISCO-codes (Petersson et al., 2011) and classified as administrative work (e.g. secretaries), patient contact (e.g. physicians) or technical staff (e.g. laboratory technician).

occupational injury were slightly younger and more often had jobs with patient contact, compared with employees with a transport or leisure-time injury, who in turn had more administrative jobs.

In Tables 2–4 odds ratios of occupational, transport and leisure-time injuries by a change in shift type or quick returns are presented. Regarding occupational injuries, evening shifts showed higher odds of an occupational injury compared with day shifts (OR 1.54, 95%CI 1.42–1.65) and night shifts (night vs. evening: OR 0.63, 95%CI 0.53–0.75). However, no statistically significant differences between night and day shifts in odds of an occupational injury were observed. In terms of quick returns, the association with occupational injuries were non-significant in the crude model, but in the adjusted model quick returns had 1.26 times higher odds of an occupational injury (OR 1.26, 95%CI 1.10–1.44) compared with 12–17 h between shifts.

We did not observe an association between evening shifts and transport injuries. However, lower odds of a transport injury were observed with night shifts compared with day shifts (OR 0.67, 95%CI 0.47–0.94). Quick returns did not show an association with transport injuries, though an indication of higher odds (with very wide confidence intervals) was seen.

In terms of leisure-time injuries, evening shifts had lower odds of leisure-time injury compared with day shifts (OR 0.87, 95%CI 0.78–0.96). No statistically significant differences in odds of a leisure-time injury between night and day shifts were found. Quick return did not show higher odds of leisure-time injuries compared with regular returns.

Result of the sensitivity analysis restricted to commuting injuries showed no statistically significant associations. Yet, estimates indicated a non-significant higher risk of commuting injuries after night shifts (model 1: OR 1.91, 95%CI 0.43–8.48) compared with day shifts and quick returns (model 1: OR 2.15, 95%CI 0.67–6.89) compared with 12–17 h.

The additional sensitivity analyses of shift definition, 24 h periods and adjustment for the prior shift, did not change the main conclusion.

4. Discussion

We observed an increased risk of occupational injury during evening shifts, but no increased risk during night shifts when compared with day shifts. Results also showed higher odds of an occupational injury following a quick return compared with 12–17 h between shifts. In terms of transport injury we observed lower odds following night shifts compared with day shifts, while no significant differences were seen in evening compared with day shifts or quick returns compared with 12–17 h between shifts. However, a sensitivity analysis indicated a higher risk of commuting injuries after night shifts compared with day shifts and quick returns compared with 12–17 h, though statistically non-significant. The odds of leisure-time injuries were lower after evening shifts compared with day shifts, while no statistically significant differences were observed after night shifts and quick returns.

4.1. Occupational injuries

Our findings of a higher risk of occupational injury during evening shifts are not fully in accordance with the findings of a newly published systematic review of occupational injury, where the authors found only a small non-significantly increased risk of occupational injuries during evening shifts (relative risk 1.12, 95%CI 0.76–1.64) compared with morning shifts (Fischer et al., 2017). On the other hand our results on evening shifts and occupational injuries are in line with the findings of two longitudinal studies (Violanti et al., 2012; Dembe et al., 2006).

We did not observe a difference in risk of occupational injuries during night shifts compared with day shifts. This is in contrast to previous studies, which suggested a higher risk of occupational injury after night shifts (Dembe et al., 2006; Fischer et al., 2017; Violanti, 2012; Violanti et al., 2012). Results from studies, which reduced unmeasured confounding between workers, also found a higher risk of occupational injury during night shifts compared with day shifts, in contrast to our findings (Ayas et al., 2006; Smith et al., 1994). Only few studies have investigated quick returns and risk of occupational injury (Trinkoff et al., 2007; MacDonald et al., 1997; Vedaa et al., 2019) and these studies are in line with our results showing a higher risk (Trinkoff et al., 2007; MacDonald et al., 1997; Vedaa et al., 2019).

4.2. Transport injuries

Results on night shifts and transport injuries in previous studies are mixed (Chiron et al., 2008; Steele et al., 1999; Stutts et al., 2003).

Table 2
Odds Ratio (OR) with 95% confidence intervals (95%CI) of risk of **occupational injury** by different work shifts characteristics.

Work shift characteristics	Exposure in case period	Reference in case period	D-exposure pairs	D-reference pairs	D-cases	Crude model		Adjusted model	
						OR	95% CI	OR	95% CI
Shift type									
Night vs. day shift (ref)	827	8852	1027	1126	1342	0.91	0.81–1.03	0.90	0.80–1.02
Evening vs. day shift (ref)	2452	8852	3585	2240	3303	1.54	1.43–1.66	1.54	1.42–1.65
Night vs. evening shift (ref)	827	2452	327	547	662	0.60	0.51–0.71	0.63	0.53–0.75
Quick returns									
≤11 vs. 12–17 h (ref)	582	7186	991	926	1225	1.11	0.97–1.26	1.26	1.10–1.44

Results from the case-crossover design with up to 5 control periods per case period. D: Discordant. Discordant exposure pairs: number of pairs with exposure in the case period and reference value in the control period. Discordant reference pairs: number of pairs with reference value in the case period and exposure in the control period. Discordant cases: number of employees with at least one discordant pair.
Adjusted model: adjusted for weekly working hours and time between shifts or shift type.

Table 3
Odds Ratio (OR) with 95% confidence intervals (95%CI) of risk of **transport injury** by different work shifts characteristics.

Work shift characteristics	Exposure in case period	Reference in case period	D-exposure pairs	D-reference pairs	D-cases	Crude model		Adjusted model	
						OR	95% CI	OR	95% CI
Shift type									
Night vs. day shift (ref)	111	2225	113	165	186	0.67	0.48–0.93	0.67	0.47–0.94
Evening vs. day shift (ref)	273	2225	436	375	451	1.17	0.95–1.43	0.99	0.81–1.22
Night vs. evening shift (ref)	111	273	51	40	67	1.19	0.72–1.97	1.23	0.74–2.04
Quick returns									
≤11 vs. 12–17 h (ref)	95	1560	168	156	206	1.06	0.78–1.44	1.09	0.78–1.53

Results from the case-crossover design with up to 5 control periods per case period. D: Discordant. Discordant exposure pairs: number of pairs with exposure in the case period and reference value in the control period. Discordant reference pairs: number of pairs with reference value in the case period and exposure in the control period. Discordant cases: number of employees with at least one discordant pair.
Adjusted model: adjusted for weekly working hours and time between shifts or shift type.

Though some studies support a higher risk of commuting injuries (motor vehicle crashes or near-by motor vehicle crashes) after night shifts compared with after day shifts (Steele et al., 1999; Stutts et al., 2003), results from a large study of French employees (n = 14,216) in electricity and gas companies did not (Chiron et al., 2008). Our results of a lower risk of transport injuries after night shifts compared with day shifts are not in line with previous studies on commuting injuries (Chiron et al., 2008; Steele et al., 1999; Stutts et al., 2003). This divergence from previous findings could be ascribed to this study including all transport injuries and not only commuting injuries. The sensitivity analysis in our study with only commuting injuries indicated a non-significant higher risk after night shifts compared with day shifts, which is in line with some results from previous studies (Steele et al., 1999; Stutts et al., 2003). However, in our study the sensitivity analysis included few cases and the precision was therefore low. Yet these results suggest that risk of commuting injuries and other leisure time transport activities may be affected by shift work differently. The differences in risk after night shifts may be explained by employees adjusting their activities during leisure time according to the level of sleepiness. Employees need to commute home after work, but transport during free time can to a higher degree be arranged under consideration of their sleepiness. In terms of evening work and commuting injuries, we have only identified one previous study (Steele et al., 1999). This study found a higher risk of commuting injury after evening shifts compared with day shifts (Steele et al., 1999), which is not in line with our results.

4.3. Leisure-time injuries

In terms of leisure-time, we did not identify any studies on night shifts, evening shifts or quick returns and risk of leisure-time injuries. The lower odds of leisure-time injuries after evening shifts compared with day shifts could be related to the timing of the leisure-time. Employees with evening work often sleep during the night and therefore have their free time in the morning before the evening shift (Åkerstedt, 2003). This could affect the activities during leisure time. Sport and other social activities are often scheduled in the evening. Thus, social activities may be limited when working evening shifts. This difference in activities may explain the lower observed risk of leisure-time injuries following evening shifts compared with day shifts.

Our findings do not provide strong support for sleepiness as part of the potential causal path between shift work and injury. First, we did not see a higher risk of occupational injuries in night shifts, where we would expect sleepiness to be most pronounced compared with other shifts. Second, we observed higher risks of injury during work (occupational injury), but not during leisure time. Thus, the higher risk of injury from certain shift work characteristics does not appear to carry-over into leisure time, though it is unclear if it affects commuting. Instead, these findings could point towards intermediate factors associated with the work shift, e.g. work tasks. As mentioned, another possibility is that employees adjust their activities depending on the level of sleepiness. This could explain our findings of lower risk of leisure time injuries after evening shifts and transport injuries after night shifts compared with day shifts. Outside of work employees are free to schedule or cancel activities. Thus, employees may plan fewer or more safe activities after a night shift compared with after a day shift. Future studies are needed to investigate whether employees after shift work adjust their activities in response to increased sleepiness, and thus add to our knowledge of the mechanisms between working hours and risk of injury.

4.4. Strengths and limitations

A major strength of this study is the three large case populations extracted from a source population of all public hospital workers in Denmark. Furthermore, register based detailed data on both exposure and outcome is an advantage, which eliminates risk of recall bias and

Table 4
Odds Ratio (OR) with 95% confidence intervals (95%CI) of risk of **leisure-time injury** by different work shifts characteristics.

Work shift characteristics	Exposure in case period	Reference in case period	D-exposure pairs	D-reference pairs	D-cases	Crude model		Adjusted model	
						OR	95% CI	OR	95% CI
Shift type									
Night vs. day shift (ref)	523	7766	575	543	698	1.07	0.91–1.25	1.12	0.95–1.32
Evening vs. day shift (ref)	1069	7766	1450	1524	1706	0.95	0.86–1.06	0.87	0.78–0.96
Night vs. evening shift (ref)	523	1069	187	204	274	0.93	0.72–1.20	0.96	0.74–1.24
Quick returns									
≤11 vs. 12–17 h (ref)	385	5712	563	538	693	1.04	0.88–1.24	0.94	0.78–1.13

Results from the case-crossover design with up to 5 control periods per case period. D: Discordant. Discordant exposure pairs: number of pairs with exposure in the case period and reference value in the control period. Discordant reference pairs: number of pairs with reference value in the case period and exposure in the control period. Discordant cases: number of employees with at least one discordant pair.
Adjusted model: adjusted for weekly working hours and time between shifts or shift type.

provides information of exposure right before the outcome. The case-crossover design eliminates time-invariant confounding by sex, occupation or commuting distance through self-matching (Mittleman and Mostofsky, 2014). Thus, the exchangeability between exposure groups is improved and differences between workers eliminated. However, the exchangeability in a case-crossover study can still be jeopardized due to confounding, selection bias, autocorrelation or time trends in exposure or outcome (Mittleman and Mostofsky, 2014). It was not possible to adjust for differences in tasks or workload between the shifts. In hospitals, tasks and workload during evening, night and day shifts may differ. Most patients will likely be asleep during the night shift and awake during the day and evening shift. Thus, confounding from task and workload could be present in this study. In addition time-variant confounding from factors such as weather and traffic density may persist. We were not able to adjust for these factors in this study. However, by selecting control periods close in time to the case period (4–8 weeks before injury) and matching on weekday, we may have reduced some potential time-variant confounding (e.g. seasonal variations). Autocorrelation between case and control periods, where the exposure in the case period dependent on exposure in the control period (Mittleman and Mostofsky, 2014), were handled by having a wash out period between the case and control periods (3 weeks), in line with a previous study (Vegso et al., 2007). Also, by selecting periods close in time we address potential long-term time trends in exposure (Mittleman and Mostofsky, 2014). We selected the most recent shift within 48 h of the injury based on a previous study (Nielsen et al., 2019). However, if prior shifts affect the risk of injury the effect may be underestimated in this study.

A limitation in this study is that the exact time of injury is not known, but approximated by the time of registration to the emergency department. As a consequence, we may not have selected the shift closest in time to the injury. However, the injury will have occurred before the time of registration at the emergency department. Also, emergency departments in Denmark normally only treat injuries that occurred within 24 h before contact (Danish eHealth Portal, 2013). This means that an injury happened sometime between the registration and 24 h before that. If the injury is severe enough to be registered at the emergency department, we assume that very few employees would have another shift after the injury, before going to the emergency department. Thus, we do not suspect any major bias from the approximation of the time of injury. Selection bias could be an issue if the registration of an injury at the emergency department depended on the shift type. However, we assume that most injuries registered at emergency departments are severe and would be registered independently of the shift type. The registration of an injury at emergency departments has changed over the years, but the registration of type of injury has previously been assessed as high (Laursen et al., 2005). In addition, it is mandatory to register the type of injury and therefore no major bias is expected from registration of type of injury.

Another limitation is dependency between exposure and outcome in occupational injuries. In the case period, the occupational injury may have led to the termination on the shift due to the injury. Thus, shift definitions of at least three hours of work within certain clock intervals could have resulted in missing values in the case period. However, the restriction to shifts of three hours was tested, by allowing shifts of all lengths in shift definitions, and this did not change the conclusions.

Our findings do not support that night shifts imply a short term higher risk of occupational injury, when compared with a day shift within the same person. However, night workers can still have a higher risk of occupational injury compared with day workers (Nielsen et al., 2018), but this increased risk may be due to other factors than the actual night shift as such. Our findings support a higher risk of occupational injuries during evening compared with day shifts and quick returns compared with regular returns between shifts. Thus, our results point towards avoiding evening shifts and quick returns to reduce the risk of occupational injuries among healthcare workers. Avoiding evening shifts may be difficult as day, evening and night shifts are necessary to provide healthcare at hospitals around the clock. Therefore future studies should explore how evening should be organised to minimise injury risk. Yet, quick returns can be avoided when scheduling working hours.

5. Conclusion

In conclusion, our findings support the evidence of a higher risk for occupational injuries during evening shifts compared with day shifts and quick returns compared with regular returns between shifts, within the same worker. However, our results suggested no increased risk of occupational injuries during night shifts compared with day shifts. Results on transport and commuting injuries were inconclusive. Finally, no higher risks of leisure time injuries after an evening shift, a night shift or a quick return was observed in this study.

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