Shift Work and the Incidence of Injury Among Police Officers

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Background *Police officers may be injury prone due to fatigue, erratic work hours, and insufficient sleep. This study explored injury incidence among police officers across shifts.*

Methods *Day-to-day shift data from computerized payroll records (1994–2010) were available from a mid-sized urban police department (n = 430). Sleep duration, shift activity level, returning to work after days off, and injury incidence over time were also examined.*

Results *Age-adjusted incidence rate ratio (IRR) for injury on the midnight shift was 72% larger than the day shift (IRR = 1.72; 95% CI = 1.26–2.36) and 66% larger than the afternoon shift (IRR = 1.66; 95% CI = 1.23–2.25). Injury incidence for the first day back on the midnight shift was 69% larger than day shift (IRR = 1.69; 95% CI = 1.23–2.32) and 54% larger than the afternoon shift (IRR = 1.54; 95% CI = 1.36–1.76). High activity level combined with midnight shift work put officers at increased injury risk (IRR = 2.31; P = 0.0003). Probability of remaining free of injury was significantly higher for day shift than midnight shift (P < 0.0001).*

Conclusions *Higher injury risk was associated with night shift work in police officers. Night shift combined with high work activity was strongly associated with injury risk. There was a significantly higher probability of not being injured on day compared to midnight or afternoon shifts.* Am. J. Ind. Med. 55:217–227, 2012.

KEY WORDS: police; occupational injury; shift work; work hours; fatigue; sleep; activity levels

INTRODUCTION

Occupational injuries are a major cause for concern. In addition to personal outcomes, the economic impact of work injuries in the United States exceeded 59 Billion dollars for unintentional injuries in 2005 [National Center for Injury Prevention and Control, Caruso et al., 2006; CDC, 2011].

Although considerable injury research has been done in various occupational groups, little work has been done concerning injury among police officers. Law enforcement is a major worldwide occupation with over 699,850 police officers in the United States alone [FBI, 2007]. Police work is hazardous and the risk of injuries is higher compared to other occupations. Reichard and Jackson [2010], using data from the National Electronic Injury

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Surveillance System, reported that police officers had the highest injury rates (8.5/100,000 full time equivalent workers) among emergency responders. The Bureau of Labor Statistics census of fatal occupational injuries [2010] reported that law enforcement had an annual rate of 14.2/100,000, higher than Emergency Medical Services (12.7/100,000). Injuries that resulted in police officer's lost time from work were similar to that of firefighters (38% vs. 39%, respectively) [Suyama et al., 2009]. From 2000 to 2009 an average of 16,041 injuries per year occurred among police officers [FBI, 2010]. The National Law Enforcement Officers Memorial Fund [2011] reported that officer deaths due to accidents in 2010 rose 35% from the previous year. Clark and Zak [1999] found that public safety personnel had a threefold increase in the rate of morbidity and mortality while working. Tiesman et al. [2010] reported that transportation-related accidents were nearly as common as homicides as a cause of injury and death among U.S. law enforcement officers. In a study of 698 police departments, there were over 2,800 injuries and more than 24,000 lost workdays, averaging 7.7 injuries and 66.4 lost workdays per agency over a period of 1 year (2002) [Zakhary, International Association of Chiefs of Police, 2008].

Fatigue, Shift Work, and Police Injury

Fatigue may be defined as an impairment of mental and physical functions, including sleepiness, reduced physical and mental performance, depressed mood and loss of motivation [Moore-Ede et al., 2010]. The chronobiological aspects of nighttime work and daytime sleep opportunities are exacerbated by social and domestic needs and rhythms, causing night shift workers to lose sleep because of the noises and demands of conventional society. As a consequence, people who work during the night and sleep during the day tend to get less sleep [Akerstedt, 2003].

The combination of insufficient sleep and the need to fight natural tendencies to fall asleep degrade alertness and performance on the job at night—increasing the risk of injury [Belenky et al., 2003]. In general, injury risks tend to be lowest on morning shifts, highest on night shifts and intermediate for evening shifts [Folkard and Tucker, 2003]. Mediation of brain processes due to fatigue may also impact accident risk. Killgore et al. [2007] suggested that sleep deprived participants showed significantly greater difficulty judging courses of action as appropriate relative to inappropriate. In such situations, persons may be more likely to have an accident or injury on a night shift.

Folkard and Lombardi [2006] reported that accidents were almost three times more likely to happen during the night shift than during the morning shift. The risk of injury increased over successive night shifts so that the fourth night shift carried 36% more risk than the first. With extended shift work hours, risk increased exponentially and in the 12th hour of work it is twice what it was during the first 8 hr [Folkard and Tucker, 2003]. In addition, reported injuries tended to be more serious and of longer duration on night shifts [Oginski et al., 2000].

In the present study, we assessed the association of shift work and risk of injury among police officers. Several hypotheses were explored: (1) officers on midnight shifts would have a higher incidence of injuries than those on day or afternoon shifts; (2) the amount of sleep (number of hours) influences the incidence of injury across shifts; and (3) due to changing circadian patterns, incidence of injury on the first day upon returning to work from a day off duty would be higher for officers on midnight shift compared to day and afternoon shifts; and the incidence of injury would continue to be higher on 2nd, 3rd, and ≥4th midnight shifts; (4) activity level will compound the incidence of injury on midnights shifts and (5) over an extended period of time, officers will have the least probability of being injured on the day shift compared to afternoon or midnight shifts.

METHODS

Study Population and Design

A total of 710 police officers in a mid-sized urban police department were invited to participate in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study and the officers were examined at a single point in time during the period of June 4, 2004 to October 2, 2009. Four hundred sixty-four officers agreed to participate (65.4%), resulting in complete data being available for 430 police officers. No specific inclusion criteria were indicated for the study, other than the participant was a sworn police officer and willing to participate in the study. Data collection was performed at The Center for Preventive Medicine, State University of New York at Buffalo. The study was approved by the Internal Review Board of the State University of New York at Buffalo, and the Human Subjects Review Board of the National Institute for Occupational Safety and Health.

For the current study, data from two sources were used. The first source of data was the BCOPS Study, a cross-sectional study where all officers were examined once during the period of 2004 and 2009. Demographic, physical, biological, and psychosocial characteristics including sleep hours and workload were collected from each participant during this time period. The second source of data was obtained by examining past payroll work history records of each participant from 1994 to date of the BCOPS Study examination. The payroll data were longitudinal in nature and is described in detail below. For each officer, the payroll data consisted of daily records of the following two variables, from 1994 to date of examination: shift worked and injury occurrence. The study has a retrospective cohort design (also termed a historical cohort design) where past payroll records were used to assess the association between the exposure of interest (shift worked) and the outcome variable (incidence of first injury).

Measures

Shift work

Actual documented work history data for a period of 16 years (1994–2010) were available for participants from computerized payroll records of the police officers (second source of data). The data contained day-by-day account of shifts, activity type, leave, sickness or injury information, and hours worked for each officer. The time participants started their shift was used to classify them into one of three categories: day shift (between 0400 and 1159); afternoon shift (between 1200 and 1959); and midnight shift (between 2000 and 0359). The majority of officers started their shift at standard shift times: 8 am, 4 pm, and 12 midnight. Officers were scheduled on 10-hr permanent shifts. Total hours worked as well as hours worked at the day, afternoon and midnight shift were computed for each participant.

Injury

The past payroll work history records (from 1994 to date of exam) were also used to ascertain new cases of injury, the date of first injury, and the shift during which the injury occurred. The work history data contained a daily indication of whether or not the officer was working. If the officer was working, the work history data shows what type of work was performed (regular work, court work, over time work, etc.), the start time of the work and the hours worked. If the officer was not working, it indicates the reason (being on vacation, sick leave, leave due to on-duty injury, etc.). A new on-duty injury was defined when the payroll record indicates that an officer is paid for regular work but is on leave due to on-duty injury. No additional information was available concerning the type of injury or its severity. There were 419 participants who were initially free of injury after excluding 4 prevalent cases and 7 cases who did not have regular time work prior to first injury. These subjects were followed over the observation period for first occurrence of a new injury.

The person time at risk was carefully assessed within the context of the outcome being studied (on-duty first injury). Hence person time at risk was expressed in terms of hours worked rather than years of service (since time off duty would be irrelevant here). The association of interest is between the shift that a participant worked and incidence of on-duty first injury and therefore a participant is at risk for on-duty injury only when the subject is at work.

Sleep duration

To assess sleep duration, officers were asked to report how many hours, on average, they slept each 24-hr period during previous seven work and off duty days. Hours of sleep reported for the two periods were averaged to give total hours of sleep per 24-hr period and dichotomized at ≤ 5 and >5 hr in accordance with sleep restriction performance bifurcation values put forth by Belenky et al. [2003].

Activity level (workload)

In most shift work situations activities performed may vary in intensity across the 24-hr workday resulting in a different work environment across shifts [Williamson et al., 2011]. To account for these differences, self-reported activity levels were collected via a questionnaire by asking all study participants regardless of the shift they work the question “What is the work activity level at your district?” with three possible answers: (1) High workload (very busy, frequent complaints, high crime area), (2) Moderate work load (moderate complaint rate, average crime), and (3) Low work load (precinct not busy, low crime area).

Statistical Analysis

Descriptive statistics were used to characterize the study population. The association of potential confounders with the exposure of interest (shift work) and the outcome variable (injury status) was examined. Chi-square tests were used to examine the association between dominant shift and categorical covariates while analysis of variance (ANOVA) was used to compare mean values of continuous covariates across dominant shift or injury status. Dominant shift was defined as the shift in which a participant spent the largest percentage of his/her total regular work time during the observation period. Incidence rate (IR) of injury by shift was first calculated manually employing the following procedures and then was later verified using a statistical model: (1) person-time (total number of hours worked in this study) at each of the three shifts was computed using work history data until the date of first injury for those with new injury and until the date of exam for those with no injury; (2) the number of participants who contributed person-time towards each shift was determined; (3) the number of participants with new first injury in each of the three shifts was determined; (4) IR of first injury for each shift was computed as the number of participants with new injuries in the specified shift divided by the total person-time for the shift and expressed per 100,000 person-hours. A similar procedure was used to compute IR of first injury by number of days back to work after being off.

Poisson regression analyses (for ungrouped data) was used to estimate IR of injury by shift and number of days back to work after being off and the associated 95% confidence intervals [Loomis et al., 2005]. Incidence rates of injury across the three shifts and across the number of days back to work after being off duty were then compared by computing incidence rate ratios (IRRs) and the corresponding 95% confidence intervals (CI). Unadjusted and age-adjusted associations between each exposure and incidence of injury were estimated. The age of the officers obtained at BCOPS Study examination was used to back-calculate age for the period starting in 1994 to date of exam. Interaction tests between hours of sleep per day and each exposure variable were conducted to assess whether sleep hours modified the primary association of interest. The combined effect of activity levels and shifts was calculated using low workload and day shift as the referent category because officers in this group were considered to be at lowest risk of injury. An alternative statistical method (survival analysis) relating time to first injury (in hours) to dominant shift of the participant during the observation period was conducted to understand how time to first injury varies by shift and also confirm the results from Poisson regression analyses. For each participant, time to first injury was calculated as the total number of hours worked at the regularly scheduled time from the first date of work history data to first date of injury (if injured) or to date of examination (if uninjured). For all tests statistical significance was assessed at the 5% level except for interaction terms. All analyses were conducted using the SAS system, version 9.2.

RESULTS

Demographic and lifestyle characteristics of study participants stratified by dominant shift are shown in Table I. The study participants consisted of 312 men and 107 women and were on average 43 years old (range: 27–70 years). The percentage of the 419 participants who

TABLE I. Demographic and Life Style Characteristics of Study Participants by Dominant Shift, BCOPS Study, 2004–2009

	Day shift, N = 174		Afternoon shift, N = 134		Midnight shift, N = 111		
Characteristics	**N**	**%**	**N**	**%**	**N**	**%**	***P*-value[a]**
Gender							
Women	66	37.9	22	16.4	19	17.1	<0.0001
Men	108	62.1	112	83.6	92	82.9	
Race							
White	126	73.3	107	81.7	93	84.6	0.1155
Black	43	25.0	22	16.8	17	15.5	
Hispanic	3	1.7	2	1.5	0	0.0	
Smoking status							
Current	26	15.1	21	15.8	21	18.9	0.0265
Former	58	33.7	27	20.3	21	18.9	
Never	88	51.2	85	63.9	69	62.2	
Rank							
Patrol officer	93	53.5	88	66.1	93	83.8	<0.0001
Sergeant/lieutenant	26	14.9	15	11.3	13	11.7	
Captain/detective	55	31.6	30	22.6	5	4.5	
Workload							
High	101	61.2	77	58.8	83	75.5	0.0151
Low/moderate	64	38.8	54	41.2	27	24.6	
Age (in years)	174	46.0 ± 8.0	134	41.2 ± 7.2	111	39.1 ± 6.7	<0.0001
Average hours of sleep/day	172	6.3 ± 1.1	133	6.3 ± 1.3	110	6.1 ± 1.2	0.2728
No. of drinks/week	170	6.5 ± 11.3	132	6.0 ± 10.4	110	4.5 ± 5.8	0.2699
Years of service	174	19.1 ± 8.5	133	15.4 ± 7.1	111	11.5 ± 6.1	<0.0001

Results for the continuous variables are means ± SD.
[a] *P*-values are from χ^2 tests of independence or Fisher's exact test for categorical variables and from ANOVA testing differences in means across dominant shift for continuous variables.

worked dominantly on the day, afternoon, and midnight shifts were 41%, 32%, and 27%, respectively (Table I). Participants on the midnight shift were younger, had fewer years of work experience, and were largely composed of patrol officers (84%) compared with the day shift. Comparison of demographic and lifestyle characteristics between injured and uninjured participants showed that injured officers were younger (41 years vs. 45 years), had fewer years of experience (14 years vs. 19 years), were more likely to currently smoke (18.1% vs. 13.6%), and spent more hours on physical activity per week compared to uninjured participants. The proportion of participants with the rank of patrol officer was greater among injured participants (76.6%) than among uninjured subjects (48%).

Table II shows IRs and IRRs of first injury by shift work. Of the 419 participants, 61% (n = 257) had a new injury during the observation period and 162 did not develop injury during the period. The number of officers who had new injuries was 86, 79, and 92 on the day, afternoon, and midnight shift, respectively. The association between shift work and injury among police officers was statistically significant. After adjusting for age, the incidence rate of injury for officers working on the midnight shift was 72% larger than for those working on the day shift (IRR = 1.72; 95% CI = 1.26–2.36, *P*-value = 0.0007), and 66% larger than for those working on the afternoon shift (IRR = 1.66; 95% CI = 1.23–2.25, *P*-value < 0.0010).

The interaction between shift work and sleep hours (≤ 5, >5) was significant ($P = 0.0923$) at the 10% level of significance and hence the association between shift work and incidence of injury was then examined with stratification by sleep hours as shown in Table III. The age-adjusted association between shift and injury (midnight vs. day comparison) was significant only for those with more than 5 hr of sleep (IRR = 1.73, *P*-value = 0.0042), whereas the comparison between midnight versus afternoon shift was significant for both groups but was stronger for those with ≤ 5 hr of sleep than for those with >5 hr of sleep (age-adjusted IRR (*P*-value): 2.88 (0.0036) vs. 1.42 (0.0383)).

Results in Table IV indicate that officers with high activity level on the midnight shift were at higher risk of injury. The incidence rate of injury for officers with combined high activity level and midnight shift was 2.3 times larger than officers with low activity level on day shifts (IRR = 2.31; 95% CI = 1.46–3.65).

The incidence rate of injury and the associated 95% CI by the number of days back to work after being off for each of the three shifts is shown in Table V and summarized in Figure 1. Generally, the incidence rate of injury on the first day back is greater than on the 2nd or 3rd or 4th day back and this is consistent across all shift categories. In addition, incidence rates of injury on the midnight shift are greater than those on the day or afternoon shifts across all categories of the number of days back to work after being off (especially on the first day back). The incidence rate of injury on the first day back for those on the midnight shift is 69% larger than those on the day shift (IRR = 1.69; 95% CI = 1.23–2.32) and 54% larger than those on the afternoon shift (IRR = 1.54; 95% CI = 1.36–1.76).

There was no evidence of interaction between shift and number of days back to work after being off (*P*-value = 0.4448) and between sleep hours and number of days back to work after being off (*P*-value = 0.6400). The pattern of injury incidence across the number of days back to work after being off is similar regardless of shift (Fig. 1), hence the association between number of days back to work after being off and incidence of injury was examined collapsing the data across shift. After accounting for age, shift work, and sleep hours, the injury incidence rate on the first day back to work after being off

TABLE II. Incidence Rate (IR) and Incidence Rate Ratio (IRR) of First Injury by Shift, BCOPS Study, 2004–2009

Shift	Number at risk[a]	Person-hours[b]	Number injured[c]	Incidence rate per 100,000 person-hours[d] (95% CI[e])	Shift	Unadjusted IRR (95% CI)	Age-adjusted IRR (95% CI)
Day	386	1668313	86	5.15 (3.13–8.49)	Midnight vs. day	2.16[÷] (1.61–2.90)	1.72[÷] (1.26–2.36)
Afternoon	356	1260168	79	6.27 (3.78–10.39)	Afternoon vs. day	1.22 (0.90–1.65)	1.04 (0.76–1.42)
Midnight	351	824611	92	11.16 (9.10–13.69)	Midnight vs. Afternoon	1.79[÷] (1.32–2.40)	1.66[÷] (1.23–2.25)

[a] The number of participants who contributed person-hours to that specific shift. Note that a participant can contribute person-hours to 1 or 2 or all three shifts but first injury occurs in only one of the three shifts.
[b] The total # of hours of work at regularly scheduled time for each shift. This is the total time (in hours) at risk for first injury.
[c] The number of participants with first injury.
[d] Incidence rate is computed as the # of participants with first injury divided by total person-hours for the shift and the result expressed per 100,000 working hours.
[e] The 95% confidence interval (CI) was computed using the Poisson regression model for ungrouped data.
[÷] *P*-value < 0.001.

TABLE III. Unadjusted and Age-Adjusted Incidence Rate Ratio (IRR) of First Injury by Shift Stratified by Sleep Hours, BCOPS Study, 2004–2009

	≤5 hr of sleep per day (N = 77)		>5 hr of sleep per day (N = 338)	
Comparison	**Unadjusted IRR (95% CI)**	**Age-adjusted IRR (95% CI)**	**Unadjusted IRR (95% CI)**	**Age-adjusted IRR (95% CI)**
Midnight vs. day	1.71 (0.88–3.32)	1.39 (0.73–2.66)	2.20 (1.55–3.13)	1.73 (1.19–2.51)
Afternoon vs. day	0.53 (0.25–1.16)	0.48 (0.22–1.05)	1.46 (1.02–2.08)	1.22 (0.85–1.76)
Midnight vs. afternoon	3.21 (1.57–6.54)	2.88 (1.41–5.86)	1.51 (1.08–2.10)	1.42 (1.02–1.97)

was approximately 38% (IRR = 1.38; 95% CI = 1.01–1.90), 46% (IRR = 1.46; 95% CI = 1.04–2.04), and 49% (IRR = 1.49; 95%CI = 1.05–2.13) larger compared to 2nd, 3rd, and 4th day back, respectively. On average, the injury incidence rate on the first day back to work was 44% (IRR = 1.44; 95% CI = 1.12–1.85) larger than that on the 2nd, 3rd, 4th, and 5th days combined, after accounting for the same covariates.

The survival curves depicted in Figure 2 represent the probability of working (surviving) past a time T without experiencing injury. Probability of remaining free of injury is much higher for the day shift and lower for midnight shift (log-rank test for homogeneity of the survival curves, P-value < 0.0001), a result consistent with the findings from the Poisson regression model.

DISCUSSION

In the present study we assessed the association of shift work with the risk of injury among police officers. Several hypotheses were explored regarding this association. Our basic proposition was that police officers on midnight shifts would have a higher incidence of injury than those on day or afternoon shifts. Results indicated that after adjusting for age, the incidence rate of injury for officers working on the midnight shift was 72% larger than for those working on the day shift and 66% larger than for those working on the afternoon shift. This result was consistent with other studies on industrial shift work and injury. Williamson et al. [2011] concluded that across multiple studies sleep related factors, show impairments in performance and increased risk of accidents or injuries. Dembe et al. [2006] found that nonstandard shift schedules were found to have a higher risk for occupational injuries and illnesses than conventional day shifts. After control for the selected covariates, the calculated hazard ratios were 1.43 (95% CI = 1.26–1.62) for evening shifts, and 1.30 (95% CI = 1.12–1.52) for night shifts.

Given that officers in the present study worked 10-hr extended shifts, this risk of injury was likely increased. Schedules with extended work hours are more risky because there is an increased total time of exposure to the work [Salminen, 2010]. In a systematic review of 25 studies on an increased injury risk among workers on extended shifts, associations were found between injury, sleepiness, and occupational stress [Robb et al., 2008]. The risks of extended shifts tended to increase exponentially in shifts longer than 8 hr. Folkard et al. [2005] found that 10-hr shifts were associated with a 13% increase in risk and 12-hr shifts with a 27% increase. Wagstaff and Sigstad [2011] found that work periods greater than 8 hr carried an increased risk of accidents that accumulates, so that the increased risk of accidents at around 12 hr of work is twice the risk at 8 hr. Salminen [2010] in a review of eight studies showed that the risk of occupational injury was 41% higher for 10-hr working days compared to 8-hr working

TABLE IV. Unadjusted and Age-Adjusted Incidence Rate Ratio (IRR) of First Injury by Shift and Work Activity Level Combined, BCOPS Study, 2004–2009

Shift/activity level[a]	Unadjusted IRR (95% CI)	*P*-value	Age-adjusted IRR (95% CI)	*P*-value
Day/low	1.00 (referent)		1.00 (referent)	
Day/high	1.33 (0.81–2.18)	0.2536	1.36 (0.85–2.19)	0.2039
Afternoon/low	1.79 (1.06–3.03)	0.0304	1.53 (0.91–2.58)	0.1112
Afternoon/high	1.25 (0.76–2.08)	0.3795	1.10 (0.67–1.81)	0.3795
Midnight/low	2.17 (1.20–3.92)	0.0097	1.75 (0.98–3.14)	0.0604
Midnight/high	2.84 (1.79–4.50)	<0.0001	2.31 (1.46–3.65)	0.0003

[a]High refers to high activity level (very busy, high complaint rate, high crime area); low refers to low (precinct not busy, low crime area) and moderate (moderate complaint rate, average crime) activity levels combined.

TABLE V. Incidence Rate of First Injury by Shift and Number of Days Back to Work After Being off, BCOPS Study, 2004–2009

Shift	Number of days back to work	Number at risk[a]	Person-hours[b]	Number injured[c]	Incidence rate per 100,000 person-hours[d] (95% CI)
Day	1	378	492955	31	6.47 (2.43–17.23)
	2	371	429899	24	4.71 (1.71–12.95)
	3	364	365479.1	12	4.49 (1.60–12.59)
	≥4	365	378512	19	4.60 (2.45–8.64)
Afternoon	1	344	391958	31	7.89 (2.94–21.14)
	2	284	339132	22	5.74 (2.08–15.89)
	3	287	282454.8	16	5.48 (1.94–15.45)
	≥4	284	233759	10	5.61 (2.97–10.60)
Midnight	1	344	260118.3	37	13.91 (7.01–27.60)
	2	283	219833.6	16	10.13 (4.95–20.74)
	3	281	187286.5	22	9.66 (4.63–20.17)
	≥4	270	156015	17	9.90 (7.08–13.84)

[a]The number of participants who contributed person-hours to that specific shift and number of days back after being off. Note that a participant can contribute person-hours to 1 or 2 or to all 12 shifts for number of days back after being off combinations but first injury occurs in only one of the 12 scenarios.
[b]The total # of hours of work at regularly scheduled time for each shift and specific number of days back after being off. This is the total time (in hours) at risk for first injury.
[c]The number of participants with first injury.
[d]Incidence rate (the # of participants with first injury divided by total person-hours expressed per 100,000 working hours) and the 95% confidence interval CI was estimated using Poisson regression for ungrouped data.

days. Another contributing factor could be the number of consecutive of workdays while on 10-hr shifts. Many departments require officers to work four consecutive days on 10-hr shifts before they have days off [Moore-Ede et al., 2010].

Our second prediction anticipated that the amount of sleep (number of hours) would influence the incidence of police injury across shifts, based on Belenky et al. [2003] finding that the bifurcation point for optimal alertness and performance is at least 4 hr of sleep. In the present study, we used a 5-hr sleep bifurcation point due to an insufficient number of officers who reported four or less hours of sleep. As expected, the comparison between midnight and afternoon shift injury was stronger for those with ≤5 hr of sleep than for those with >5 hr of sleep.

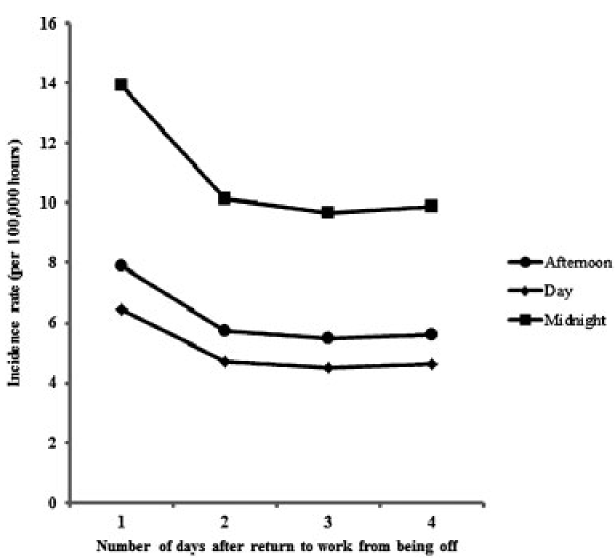

FIGURE 1. Incidence of first injury and number of days back to work after being off duty.

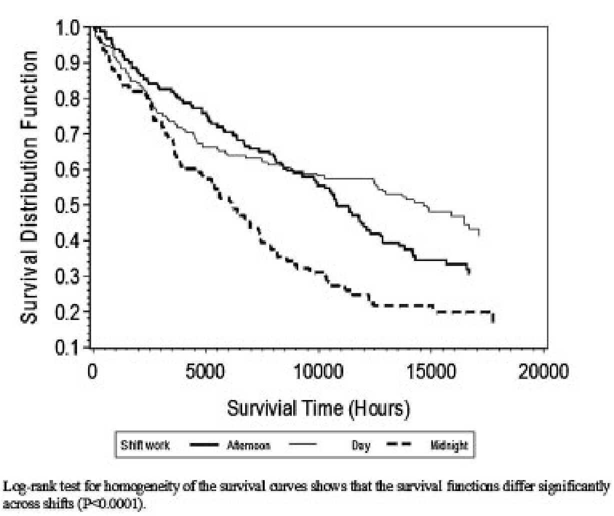

FIGURE 2. Survival function of first injury by shift for all participants.

Unexpectedly, the age-adjusted comparisons between the midnight and day shift were slightly stronger for those with >5 hr of sleep than for those with ≤5 hr of sleep. We did not have sufficiently detailed data on officers to adequately explain this result. Regardless of shift worked, Van Dongen et al. [2003] report that restriction of sleep to 6 hr or less per night produced cognitive performance deficits equivalent to up to two nights of total sleep deprivation, suggesting that sleep debt is perhaps best understood having a neurobiological cost which accumulates over time.

Third, we proposed that due to changing circadian patterns, the incidence of injury on the first day upon returning to work from a day off duty would be higher for officers on midnight shift; and the incidence of injury would remain higher on 2nd, 3rd, and ≥4th midnight shifts compared to day and afternoon shifts. The incidence rate of injury on the first day back for those on the midnight shift was 69% larger than those on the day shift and 54% larger than those on the afternoon shift. The incidence rate of injury on the first day back was greater than on the 2nd or 3rd or 4th day back consistently across all shift categories.

According to Santhi et al. [2007], midnight shifts pose a challenge because of the biological pressure to sleep at night. They add that cognitive deficits are likely to be most acute during the transition from a day to a night shift, being most pronounced on the first night shift. Shift workers tend not to compensate for sleep lost during the work week by getting more sleep on their days off [Tepas, 2003]. There was a significant difference in injury incidence during the first day back on midnight shift duty when compared to either of the other shifts, in addition to the expected result that the incidence of injuries was greater throughout the work week during midnight shifts. This indicates that the impact of this effect is significantly greater for midnight shift workers, perhaps because they tend to have fewer sleep opportunities and the difference between their work times and mainstream society's social activities are so much greater. Evidence suggests that night shift workers often arise at a ''normal'' time with their families on their last day off, then go on to begin work fourteen or more hours later—sometimes without even napping. Officers can be fatigued at the hour they actually check in for duty. This would be a possible cause of the first-day-back effect [Vila and Kenney, 2002].

Hypothesis four predicted that higher work activity levels would further compound the association between injury incidence on midnight shifts compared to day shifts. Our results suggested that officers with high work activity levels who also worked the midnight shift were at higher risk of injury. Comparing ''high activity and midnight shift'' to ''low activity and day shift'' showed that the incidence rate of injury for officers with combined high activity and midnight shift work was 2.3 times larger than officers with low workload on day shift.

Tasks requiring vigilance or sustained attention have been noted as fatigue-prone factors on jobs where sustained attention is important [Warm et al., 2008]. Police work is an occupation that requires vigilance at all times, especially in areas of jurisdiction where there are high activity levels. Much of police work is stressful, and a high activity level can certainly exacerbate stress, leading to mental and physical fatigue. Collins and Gibb [2003] found that lack of control over activity levels, inadequate support and excess activity levels were common stressors mentioned by police officers.

In the context of the Demand–Control model, adverse reactions of psychological strain can occur (fatigue, anxiety) when decision latitude in the task is low and the demand (work pace) is high [Karasek et al., 1998]. Under conditions of high work activity, the officer has little control over the pace of stressful and traumatic event demands at work. Answering citizen complaints and investigation of accidents, assaults and homicides all take their toll on fatigue and stress. In a midnight shift environment of high demands the outcome of psychological strain along with circadian disruption can result in increased physical and mental fatigue and risk of injury or accidents [Violanti et al., 2009; Webb et al., 2011].

Our fifth proposition concerned the probability of being injured on the day shift versus afternoon or midnight shifts over an extended period of time (work hours). Results indicated that over time probability of remaining free of injury is significantly higher for day shifts compared to midnight shifts (log-rank test for homogenity of the survival curves, P-value < 0.0001). This is an interesting result, as Folkard and Lombardi [2006] commented that there is little evidence for injury risk over longer spans of successive night shifts. Additionally, we were able to compare the risk of injury across all three shifts as well. Results indicated that officers who worked night shifts were at higher risk for injuries than those who worked other shifts over an extended period of time, further implicating night work as having a higher incidence of injury.

Strengths and Limitations

To our knowledge, this study is among one of the first inquiries into shift work and injury among police officers. While other studies have suggested that injury to police officers occurs more frequently on midnight shifts, they have not systematically examined this hypothesis based on multiple years of objective, day-to-day work records of officers. Most studies have relied heavily upon self-report data concerning shift work. In addition the influence of shift work was assessed in relation to subsequent incidence of injury. We were also able to effectively take into account important contributing factors to injury such as age, hours of sleep, activity level, and successive shifts. In addition, utilizing survival analysis, we were able to predict the effect of shift work on injury over an extended number of work hours, a result likely not possible with self-report short-term data.

As with most other studies to date, we had limited data on some additional factors which may have impacted fatigue and the circumstances of the injury. Lack of information on the exact time of the injury prevented us from further clarifying the effects of shift work on injury. According to Folkard and Tucker [2003], studies have shown significant dips in vigilance between 10 pm and 6 am, with a trough at 3 am, the risk of injury being 30% higher on night compared to day shift in the first 2–3 hr. With extended working hours, as is the case in our police sample, risk increases more or less exponentially with extended hours of work where it is twice what it was during the first 8 hr [Nag and Patel, 1998; Folkard and Tucker, 2003].

The question of types and severity of injuries could not be addressed directly using the current work history data since the data do not indicate the source of the injury (injury from car crash, injury inflicted by a criminal, injury from fall while chasing a suspect, etc.). However, previous work has outlined injury among police officers. For example, the International Association of Chiefs of Police reported that sprains were the most frequent class of police injuries reported, accounting for 47% of all officer injuries. Broken bones accounted for 21% of the lost workdays, but only 5% of the injuries. More than half (51.9%) of the respondents reported that most injuries occur between the hours of 6 pm and midnight [Zakhary, 2008]. An examination of police compensation claims between 2006 and 2007 resulting in injury to Australian police found that injuries varied during different activities. Some examples were: (1) open wounds to the hand (12%) were the result of being assaulted by another person, (2) muscle and tendon sprains to the back (11%) resulted from chasing offenders on foot and falling over; getting out of vehicles onto uneven ground and falling; tripping over objects on the ground; arresting or restraining offenders, (3) neck injuries (5%) due to vehicle accidents; and (4) ankle injuries (5%) due to falling when getting out of vehicles; chasing offenders on foot; tripping on uneven ground surfaces (Police injuries, 2011, http://www.deir.qld.gov.au/workplace/resources/pdfs/ shearing.pdf).

Reichard and Jackson [2010] reported that the primary events for all injuries to law enforcement officers were assaults and violent acts (26%) and bodily motions (19%). Another person was involved in 86% of the assaults and violent acts and 17% of the bodily motion related injuries. The primary source of 70% of bodily motion related injuries (i.e., largely sprains and strains) was the body condition, motion, or position of the injured officer. Tiesman et al. [2010] found that the most prevalent causes of transportation-related death for the protective service category "Police and Detectives" was driving to the scene of a police call (62%).

Since sleep hours and workload were collected after the injury, the analyses involving sleep hours and activity level (workload) assumes that self-reported sleep hours and activity level assessed at the time of examination generally represents a reasonable estimate of their sleep hours and activity levels for the period under consideration (1994 to date of exam). It is possible that sleep hours and activity levels might have changed over time. It is likely that this type of misclassification, if present, would have underestimated the associations observed.

Although the participation rate was 65%, the gender and race distributions of the study sample were similar to that of all officers employed around the time of the study examination. The study sample and all employed officers had nearly identical percentage of males (74.5% and 75.6%, respectively) and the distribution by race included 79% white and 20% black for the sample versus 66% white and 24% black for all officers. The similarity in these demographic characteristics suggests that the sample of officers who participated in this study may be representative of all officers employed at that time.

In addition, beginning in 1994 study participants worked a fixed rather than a rotating shift except for instances where they were asked to fill in for another officer or were called in to duty on a different shift. For example, 74% of subjects with day as their dominant shift spent over 70% of their person time at risk on the day shift; 62% of subjects with afternoon as their dominant shift spent over 70% of their person time at risk on the afternoon shift; 60% of subjects with midnight as their dominant shift spent over 70% of their person time at risk on the midnight shift. However, the analytic method (ungrouped Poisson regression) employed in this study used daily records of shift worked rather than the dominant shift and hence took into account person time at risk accumulated by a subject at all three shifts.

Intervention

It is important to design shift systems in a manner that minimizes injury risk, especially in critical occupations like policing where there may be danger to officers as well as the general public. Police organizations should consider changes in scheduling practices for officers working overtime and extended tours of duty such as 10- or 12-hr shifts [Dembe et al., 2005]. One suggestion is to employ prediction models such as the survival curve in the present study to help predict time points of greatest injury risk and adjust schedules accordingly. Another suggestion is to rotate officers out of high activity areas to help reduce both mental and physical fatigue.

Implementing safer shift schedule designs does not address the entire problem. It is also important to create a culture in which officers receive adequate information about the importance of good sleep habits, the hazards associated with fatigue and shift work, and strategies for managing them. In theory, there is no one ''best'' shift for police officers. Working atypical hours will always remain a part of this occupation as the safety and security of the public is at risk 24 hr a day. The recent movement of police departments throughout the United States to employ extended shifts (10- or 12-hr shifts) complicates this issue. Because the social, organizational, and individual causes of sleep loss among police officers are inextricably linked, systematic interactions must be taken into account to better understand sleep deprivation issues and injuries in this critical population [Vila, 2005; Vila and Samuels, 2010].

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REFERENCES

Akerstedt T. 2003. Shift work and disturbed sleep/wakefulness. Occup Med 55:89–94.

Belenky G, Wesensten NJ, Thorne DR, Thomas ML, Sing HC, Redmond DP, Russo MB, Balkin TJ. 2003. Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-dependent study. J Sleep Res 12:1–12.

Bureau of Labor Statistics census of fatal occupational injuries. 2010. Workplace injuries and illnesses—2009. USDL-10-1451. http://www.bls.gov/.

Caruso CC, Bushnell T, Eggertth D, Heitmann A, Kojloa B, Newman K, Rosa R, Sauter SL, Vila B. 2006. Long working hours, safety, and health: Toward a national research agenda. Am J Ind Med 49:930–942.

Clark C, Zak MJ. 1999. Fatalities to law enforcement officers and firefighters, 1992–1997. Comp Work Cond 4:3–7.

Collins PA, Gibb AC. 2003. Stress in police officers: A study of origins, prevalence and severity of stress-related symptoms within a county police force. Occup Med 53:256–264.

Dembe AE, Erickson JB, Delbos RG, Banks SM. 2006. Nonstandard shift schedules and the risk of job-related injuries. Scand J Work Environ Health 32:232–240.

Dembe AE, Erickson JB, Delbos RG. 2005. The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the United States. Occup Environ Med 62:588–597.

FBI. 2007. Crime in the United States 2007. http://www.fbi.gov/.

FBI. 2010. Police deaths, assaults, and injuries. http://www.nloemf.com/fcats/officer-fatalities-data/daifacts.html.

Folkard S, Lombardi DA, Tucker PT. 2005. Shiftwork: Safety, sleepiness and sleep. Ind Health 43:20–23.

Folkard S, Tucker P. 2003. Shift work, safety, and productivity. Occup Med 53:95–101.

Folkard S, Lombardi DA. 2006. Modeling the impact of the components of long work hours on injuries and accidents. Am J Ind Med 49:953–963.

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. 1998. The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 3:322–355.

Killgore WD, Killgore DB, Day LM, Li C, Kamimori GH, Balkin TJ. 2007. The effects of 53 hours of sleep deprivation on moral judgment. Sleep 30:345–352.

Loomis D, Richardson DB, Elliott L. 2005. Poisson regression analysis of ungrouped data. Occup Environ Men 62:325–329.

Moore-Ede M, Davis W, Sirois W. 2010. Advantages and disadvantages of twelve hour shifts: A balanced perspective. Circadian Workforce Solutions, http://www.circadian.com/.

Nag PK, Patel VG. 1998. Work accidents among shift workers in industry. Int J Ind Ergon 21:275–281.

National Center for Injury Prevention Control, CDC. 2011. Estimated number of non-fatal injuries and estimated lifetime costs classified by mechanism and intent, ages 20–65, United States, 2005. http://CDC.gov.

National Law Enforcement Officers Memorial Fund. 2011. After 50 year low, law enforcement fatalities surge 43% in first half of 2010. http://www.nloemf.com.

Oginski A, Oginska H, Pokorksi J, Kmita W, Gozdziela R. 2000. Internal and external factors influencing time related injury risk in continuous shift work. Int J Occup Safety Health 6:405–421.

Police injuries. http://www.deir.qld.gov.au/workplace/resources/pdfs/shearing.pdf. Accessed August 15, 2011.

Reichard AA, Jackson LL. 2010. Occupational injuries among emergency responders. Am J Ind Med 53:1–11.

Robb G, Sultana S, Ameratunga S, Jackson R. 2008. A systematic review of epidemiological studies investigating risk factors for work-related road traffic crashes and injuries. Inj Prev 14:51–58.

Salminen S. 2010. Shift work and extended working hours as risk factors for occupational injury. Ergon Open J 3:14–18.

Santhi N, Horowitz TS, Duffy JF, Czeisler CA. 2007. Acute sleep deprivation and circadian misalignment associated with transition onto the first night of work impairs visual selective attention. PLoS ONE 2(11):e1233. DOI: 10.1371/journal.pone.0001233.

Suyama J, Rittenburger JC, Patterson PD, Hostler D. 2009. Comparison of public safety provider injury rates. Prehosp Emerg Care 13: 451–455.

Tepas DI. 2003. The impact of shiftwork on manufacturing and transportation workers. In: Karwowski W, Noy I, editors. Handbook of Forensic Human Factors and Ergonomics. London: Taylor and Francis.

Tiesman HM, Hendricks SA, Bell JL, Amandus HA. 2010. Eleven years of occupational mortality in law enforcement: The census of fatal occupational injuries, 1992–2002. Am J Ind Med 53:940–949.

Van Dongen H, Maislin G, Mullington JM, Dinges DF. 2003. The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 26:117–126.

Vila BJ. Managing Police Fatigue: A High-Wire Act. 2005. Royal Canadian Mounted Police Gazette 70. Online at http://www.rcmpqrc.qc.ca/gazette/vol7Ono3/fatiquee.html.

Vila BJ, Samuels C 2010. Sleep loss in police and implications for other first responders and the military. In: Kryger MH, Roth T, Dement WC, editors. Principles and practice of sleep medicine, 5th edition, Chapter 72.

Vila BJ, Kenney DJ. 2002. Tired Cops. NIJ Journal 248. Accessed in September 2011. http://www.ncjrs.gov/pdffiles1/jr000248d.pdf.

Violanti JM, Burchfiel CM, Hartley TA, Mnatsakanova A, Fekedulegn D, Andrew ME, Charles LE, Vila BJ. 2009. Atypical work hours and metabolic syndrome among police officers. Arch Environ Occup Health 64:194–201.

Wagstaff AS, Sigstad L. 2011. Shift and night work and long working hours-a systematic review of safety implications, Scand J Work Environ Health 37:173–185.

Warm JS, Parasuraman R, Mathhews G. 2008. Vigilance requires hard mental work and is stressful. Hum Factors 50:433–441.

Webb HE, Garten RS, McMinn DR, Beckman JL, Kamimori GH, Acevedo EO. 2011. Stress hormones and vascular function in firefighters during concurrent challenges. Biol Psychol 87:152–160.

Williamson A, Lombardi DA, Folkard S, Stutts J, Courtney TK, Connor JL. 2011. The link between fatigue and safety. Accid Anal Prev 43:498–515.

Zakhary YA. 2008. A zero tolerance approach to officer injuries. Police Chief LXXV:1–6.