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Original article

Risk factors for unintentional occupational injury among urban transit bus drivers: a cohort longitudinal study

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ABSTRACT

Purpose: Although many studies have focused on bus operators' occupational diseases, work-related injury and associated risk factor data are limited. The purpose of this longitudinal study was to investigate unintentional injury and exposures that may affect injury risk among metropolitan bus operators.
Methods: Demographic, work-related, and injury data obtained from a metropolitan transit company for a 5-year period, enabled estimates of rates per 100 full time equivalents (FTEs) and adjusted Hazard Ratios (HRs), with 95% confidence intervals (CIs), using Generalized Estimating Equations and Cox proportional hazards models, respectively.
Results: The 2095 bus operators, included in this study, had an unintentional injury rate (95% CI) of 17.8 (16.1–19.7) per 100 FTEs. Multivariable analysis identified increased risks for operators who were female, compared to male (HR = 2.4; 2.0–2.8); worked less than 7 versus 7 to less than 12 hours per day (HR = 4.6; 3.8–5.5); and drove less than 7 versus 7 to less than 12 hours per day (HR = 3.2; 2.7–3.8). Suggestive increased risks were identified for operators working split versus straight shifts (HR = 1.2; 1.0–1.4) and for driving limited versus regular bus routes (HR = 1.36; 1.0–1.8).
Conclusions: Results serve as a basis for further studies and inform the development of targeted intervention strategies to reduce bus operators' occupational injuries.

Introduction

From prior studies, professional bus operators are reportedly at high risk of three important physical health problems: cardiovascular disease; gastrointestinal disorders; and musculoskeletal problems [1–4]. Among those, stress was identified as a primary factor associated with cardiovascular disease and gastrointestinal disorders [2,5,6]. Karasek's demand-control model [7] suggested four categories of psychological work experiences, illustrated by two dimensions: high or low job demand and high or low job control. Bus operators have been classified as having high job demand with low job control [1,7], a combination associated with mental strain and job dissatisfaction [7]. The stress may be induced by their working characteristics, including irregular shifts, strict time schedules, adverse bus incidents, and limitations in break times and social support. Contrary to other vehicle-type drivers, bus operators engage in multiple activities that include assisting disabled/elderly passengers, and managing fare-evading riders, besides focusing on traffic conditions. High correlations have been reported between psychological job demands and encounters with bus incidents (mechanical failures, with crashes) and emergency route modifications [8].

Bus operators' shifts are often longer than for other occupations and frequently result in continuous work without rest or meal breaks. From one longitudinal study of youth, higher hazard rates for occupational injuries and illnesses were reportedly associated with working more than 60 hours per week, more than 12 hours per day, and overtime, when adjusted for age, gender, occupation, industry, and region [9]. Bus operators have also been reported to have a high prevalence of work-related musculoskeletal disorders (WMSDs) [1,2,10] that are also associated with psychosocial risk factors [1,11]. Exposure to prolonged sitting, vibration, and restriction for long periods in their cabin area, may contribute to increased

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physical loading in the musculoskeletal system, resulting in back pain [10,11].

In 2012, the Bureau of Labor Statistics reported that the "bus drivers' transit and intercity" occupation category, compared with all other occupational categories, had the highest total incidence rate for nonfatal occupational injuries and illnesses (851.5 vs. 112.4 per 100,000 full-time workers). In particular, the "multiple traumatic injuries and disorders" category rate was six times greater than all occupations combined (25.6 vs. 4.3 per 10,000 full-time workers) [12], WMSD rates for this, and all occupational categories, were 146.2 and 33.0, respectively [13]. Although this occupational category included more than the transit bus operators, addressed in the present study, the data identified the magnitude, to some degree, of the transit operators' problem.

Although numerous studies have focused on bus operators' occupational diseases and other health outcomes that provided a basic understanding for this study, limited data address the realm of bus operators' work-related injuries and relevant exposures. The present study addressed the work-related unintentional injury problem among transit bus operators in a large metropolitan area in Minnesota to determine the incidence and potential risk factors—information that can provide a basis for relevant intervention efforts.

Methods

Study design

The ultimate goal of this longitudinal cohort study was to identify how personal and work-related characteristics may contribute to the occurrence of work-related injuries among transit bus operators. This involved first identifying the magnitude and consequences of these injuries for a 5-year period of time, followed by analysis to determine the associations between occupational injury and exposures of interest that enable identification of relevant risk factors. This study was approved by the Institutional Review Board at the University of Minnesota.

Study population and data collection

The study population consisted of transit bus operators employed at a metropolitan transit company serving a seven county area in Minnesota that encompassed 907 square miles, including 90 cities. Available data, between December 1, 2006 and December 31, 2011, were obtained from the company; data included bus operators' demographic information and work-related characteristics and exposures. No direct contact was made with the bus operators.

There were 2095 total eligible bus operators employed during the study period. Those departing before December 1, 2006 or entering after December 31, 2011 were excluded from the data analysis.

Measurements and definitions

Dependent variable—unintentional injury events

Definitions used for work-related injury are consistent with the National Center for Health Statistics (NCHS) and Bureau of Labor Statistics [14]. Work-related injuries are any wounds or damage to the body associated with the job that occurs in the work environment. In particular, unintentional injury involves unexpected transfer to a person or group of persons by some form of energy (mechanical/kinetic, chemical, electrical, and so forth) within the environment that exceeds the physical tolerance threshold. The injury report information included event date; event time; type of injury ("burn or scald," "caught in or between," "puncture, or scrape," "fall or slip injury," "motor vehicle related," "abrasion," "strain," "striking against or stepping on," and "struck by"); and body part affected (arm, back, chest, hand, head, leg, and shoulder). From these reports, 1389 injury events were identified; these events were reviewed and classified by the investigators, based on the aforementioned definitions. After eliminating cases that did not meet the requirement (e.g., non–work-related, chronic injury), 1265 work-related injury events were included in the final data analysis.

Independent variables

Personal characteristics. Age (<30, 30 to <40, 40 to <50, 50 to <60, and 60 + years) and gender (male and female) were included as demographic characteristics, given the potential for variations in injury occurrence [12].

Occupational characteristics. Bus garages were comprised of five transit company garages and associated bus routes, based on geographic locations that are representative of the variations in route difficulties.

Job classification was categorized as weekday full-time (40 hours of work per week guaranteed), weekday part-time (≤30 hours per week), and weekend part-time.

Working years were defined as total time in years worked at the transit company.

Workload was defined as hours of driving and working per day, including overtime hours.

Work shifts involved two types of shift work; a straight shift equaled a regular day shift and a split shift involved a workday split into two periods.

Number of bus routes could range from one to seven different routes since each operator could have multiple driving assignments within a day.

Types of bus routes were comprised of three types: regular-route; limited stops (same as regular-route with less stops); and express bus service (freeway travel for at least four miles; higher fares, compared with other routes).

Work start time was categorized in 3-hour time blocks, starting at midnight. Eight subcategories of working time commencement were: 12 AM to <3 AM; 3 AM to <6 AM; 6 AM to <9 AM; 9 AM to <12 PM; 12 PM to <3 PM; 3 PM to <6 PM; 6 PM to <9 PM; and 9 PM to <12 AM.

Statistical analysis

Data analysis commenced with descriptive statistics, including number of reported events and consequences and characteristics of exposures of interest. The outcome variable (work-related injuries) involved analysis of the number of events occurring in a set of observations; in this study, a transit bus operator could have reported more than one injury event during the study period.

Estimates of rates, per 100 full time equivalents (FTEs), and associated 95% confidence intervals (CI), were generated using generalized estimating equations (GEEs) [15] with exchangeable working correlation matrices. FTEs were calculated, using the total number of working hours within the study period, divided by 2000 hours (8 hours/day* 5 days/week* 50 weeks per year). GEEs are an extension of generalized linear models to correlated data; they produce marginal models, which calculate average estimates across subjects (bus operators), while accounting for the dependency between repeated measures within subjects. In this study, bus operators selected or were assigned their work shifts and schedules three to four times a year; their work-related characteristics could have changed, based on their daily shift assignments.

Thus, each observation was based on their assignments, per day, and could have involved up to 250 observations for each bus operator per year; therefore, each observation was time-independent, and observations were correlated within a bus operator. In the models, each bus operator was considered independent. The exchangeable working correlation structure assumes that any two observations within a subject (bus operator) have a consistent correlation, providing the rationale for using exchangeable working correlations in the GEE models for each exposure of interest.

To estimate the impact of various risk factors on the occurrence of occupational injury, Cox proportional hazards analysis was utilized. Each bus operator was observed and considered at risk until the injury event occurred. The Cox proportional hazards models enable regression of this "survival" time on the potential risk factors and adjust for other factors included in the models. As noted, this longitudinal data set contained repeated observations, and one bus operator could have reported more than one injury event; therefore, the "counting process model" for Cox proportional hazard analysis was utilized in the analytical model. This model assumed each reported injury event within a bus operator was independent, that is, a subsequent event was not related to any previous event; thus, the sequence of the injury events was disregarded. All analyses were conducted using SAS software, version 9.4 of the SAS system for windows [16].

Selection of variables

A causal model [17], based on transportation specialists' expertise (the transit company field operations and risk managers) and limited relevant literature [18–21], was developed to determine the variables to be measured and controlled for in the overall analyses (Fig. 1). Although the target populations of the studies reviewed in the literature were not limited to bus operators, some of the identified risk factors were considered as potentially important to the present study. These included hour of the day, hour of shift start, and shift work, which were identified as risk factors for occupational injuries among various occupations, including bus drivers [18,19]. One study used the National Longitudinal Survey of Youth (NLSY) data to examine occupational injuries among different races and ethnicities and reported that working full-time and having longer tenure were risk factors for occupational injuries [20].Another study reported that the types of work-related injuries reported, such as sprains and strains, were higher on Mondays compared with other days of the week [21].

From the overall causal model, individual directed acyclic graphs (DAGs) were derived to select, a priori, the minimum set of potential confounding factors for each exposure of interest and guide multivariable analyses of the data [17,22,23]. Adjusted hazard ratios (HRs) and associated 95% CIs, per 100 FTEs, were calculated to determine the strength of the associations between exposures and the outcome of interest. For example, because operators could select their own work shifts and schedules three to four times a year, based on their seniority (time employed), working years was the confounding factor and controlled for when examining the associations between operators' working schedules or shifts (exposures of interest) and work-related injury. A DAG example, used in the multivariable analysis, is shown in Figure 2, in which an adjusted HR for work start time (exposure of interest) was calculated after adjustment for age, gender, work years, job classification, work shift, and bus garage.

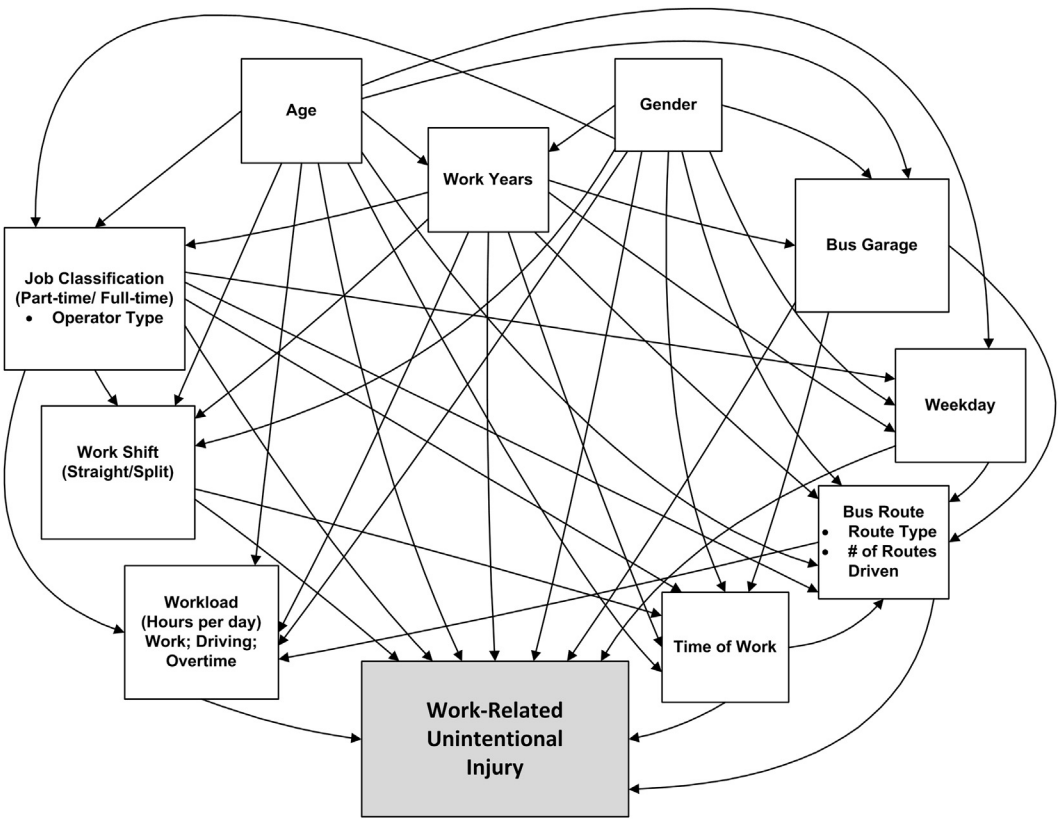

Fig. 1. Causal model: metropolitan transit bus operator study, 2006–2011.

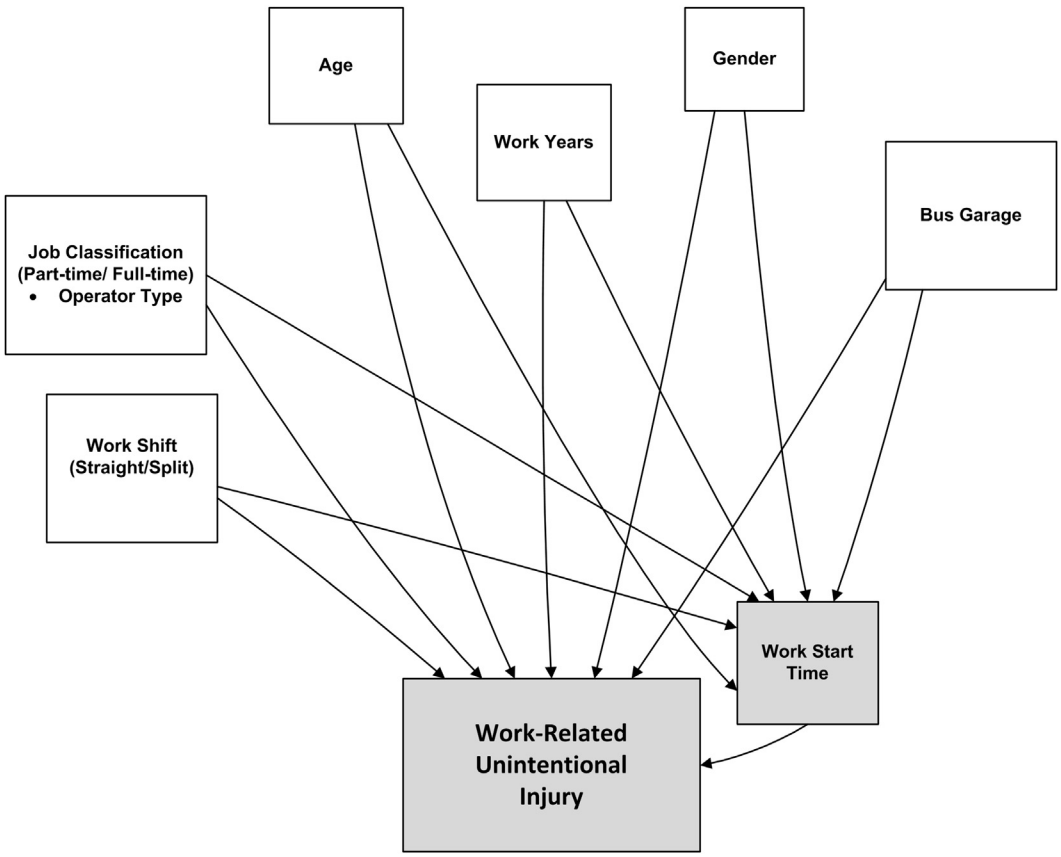

Fig. 2. Example of directed acyclic graph (DAG) for work start time: Minnesota metropolitan transit bus operator study, 2006–2011.

Results

A total of 2095 bus operators were included in this study; primarily, they were male (78%), with a mean age of 49 years (standard deviation [SD] = 10) and mean working time of 11 years (SD = 9). Average working, driving, and overtime hours per day for full-time and part-time workers are shown in Table 1; average working and driving hours per day were greater for full-time versus part-time bus operators. Table 2 identifies the numbers and percentages of bus operators who reported injuries during the study period, ranging from 0 to 1, to multiple events, accounting for a total of 1265 unintentional injury events reported during the 5-year period. According to the injury reports, 30% ($n = 636$) of the bus operators reported at least one injury event during the five-year study period (December 01, 2006–December 31, 2011).

As noted, this was a longitudinal study; therefore, the work-related characteristics and exposures were time-dependent and could change from day-to-day. Table 3 identifies the numbers and percentages of reported events by operator characteristics and exposures on the dates of injury during the 5-year period. The majority of injury events were reported by bus operators who were between the ages of 40 and 59 years; worked for less than 10 years; working full-time; starting their shifts between 3 AM and 9 AM; working and driving 7 to less than 12 hours; and driving two routes or more.

The primary types of reported injuries were strains, followed by fall or slip injuries; back and leg injuries occurred most frequently. Additional reported types of injuries and associated body parts are shown in Table 4.

Table 1
Average working, driving, overtime hours and Standard Deviation (SD) per day, by job classification: metropolitan bus operator study, 2006–2011

Working, driving, and overtime hours/day	Job classification		Overall
	Full-time	Part-time	
Working hours/day (SD)	8.6 (1.5)	5.8 (1.9)	7.8 (2.0)
Driving hours/day (SD)	8.1 (1.9)	5.5 (1.8)	7.4 (2.2)
Overtime hours/day (SD)	0.3 (1.3)	0.8 (2.3)	0.4 (1.6)

Table 2
Numbers and percentages of bus operator–reported injury events: Metropolitan bus operator study, 2006–2011

No. of events reported by bus operator	No. of bus operators	%
0	1459	69.64
1	351	16.75
2	145	6.92
3	66	3.15
4	31	1.48
5	12	0.57
6	14	0.67
7	7	0.33
8	2	0.10
9	2	0.10
10	1	0.05
11	1	0.05
12	2	0.10
13	0	0.00
14	1	0.05
15	0	0.00
16	1	0.05
Total	2095	100

Table 3
Characteristics of injured bus operators and exposures on the dates of injury: metropolitan bus operator study, 2006–2011

Total events = 1265	No. reporting events	%		No. reporting events	%
Age (years)			Driving hours		
< 30	58	4.6	0 hours	3	0.2
30 to <40	157	12.4	>0 to less than 7 hours	471	37.2
40 to <50	372	29.4	7 to less than 12 hours	775	61.3
50 to <60	483	38.2	≥12 hours	16	1.3
60 +	195	15.4	Overtime hours		
Work Years			0 hours	1159	91.6
0 to <5	315	24.9	>0 to less than 3 hours	65	5.1
5 to < 10	367	29.0	3 to less than 6 hours	30	2.4
10 to <15	229	18.1	≥6 hours	11	0.9
> 15	354	28.0	Number of Routes Driven		
Job Classification			None	3	0.2
Full-time	1029	81.3	One Route	561	44.3
Part-time	236	18.7	Two Routes	387	30.6
Work Start Time			More than three routes	290	22.9
12 AM to <3 AM	8	0.6	Unknown	24	1.9
3 AM to <6 AM	505	39.9	Route Type Driven		
6 AM to <9 AM	357	28.2	None	3	0.2
9 AM to <12 PM.	106	8.4	Regular only	613	48.5
12 PM to <3 PM	177	14.0	Limited Stop only	55	4.3
3 PM to <6 PM	108	8.5	Express Bus only	129	10.2
6 PM to <9 PM	3	0.2	Regular and Limited Stop	115	9.1
9 PM. to <12 AM	1	0.1	Regular and Express Bus	185	14.6
Working Hours			Limited Stop and Express Bus	41	3.2
>0 to less than 7 Hours	439	34.7	Regular, Limited Stop, and Express Bus	109	8.6
7 to less than 12 Hours	807	63.8	Unknown Type	15	1.2
≥12 Hours	19	1.5	Shift		
			Straight	890	70.4
			Split	375	29.6

Table 5 identifies the results of the estimated unintentional injury rates per 100 FTEs and associated 95% CIs, adjusted hazard ratios (HRs) and associated 95% CIs, and working hours for each exposure of interest. Factors controlled for in each multivariable model are identified at the bottom of the table. Overall, the GEE analysis identified an injury rate of 17.8 per 100 FTEs among transit bus operators; although male, compared with female, operators reported more events, their estimated rate was lower. Injury rates increased with age and varied from 12.6 to 21.3 per 100 FTEs. Bus operators, who worked less, and drove less, than 7 hours per day, had the highest injury rates. Through multivariable analyses, adjusted HRs indicated female compared to male operators had an increased risk of injury. Higher risks were evident for operators who worked less, and drove less than seven, versus seven to less than 12 hours per day. Operators who worked split, versus straight shifts, demonstrated a 20% higher injury risk. In addition, a 40% higher injury risk was identified for bus operators who drove limited versus regular bus routes. Decreased risks were found among operators who had worked less than 5 versus 15 years; part-time compared to full-time; part-time during weekday compared to full-time 8 hours; and drove two or more than three routes, compared to those who drove only one route. Moreover, operators who worked on Mondays, Thursdays, and Saturdays, compared to Sunday, had decreased risks.

Table 4
Type of injury and associated body part: metropolitan bus operator study, 2006–2011

Unintentional injuries reported		
Total events = 1265	Number	Percent
Type of injury		
Strain	736	58.2
Fall or slip injury	177	14.0
Struck by	95	7.5
Motor vehicle-related	84	6.6
Striking against or stepping on	74	5.8
Miscellaneous causes	54	4.3
Puncture or scrap	17	1.3
Caught in or between	14	1.1
Burn or scald/heat or cold exposure	13	1.0
Abrasion	1	0.1
Body part		
Back	272	21.5
Leg	248	19.6
Multiple body part	188	14.9
Shoulder	168	13.3
Hand	148	11.7
Head	118	9.3
Arm	68	5.4
Chest	21	1.7
Unknown	19	1.5
No physical injury	15	1.2

Discussion

This study determined the incidence of and potential risk factors for work-related injuries among transit bus operators in a metropolitan area. The overall unintentional injury rate was 17.8 per 100 FTEs; due to different study methods and populations used, it is difficult to compare this rate with other studies.

While it has been reported that males are more likely than females to experience work-related injuries, in general [12,24–26], it was identified in the present study that females had a higher risk. In addition to injury risk, occupational studies have suggested that females experience greater injury severity compared to males; one population-based study, utilizing workers' compensation data, indicated females had longer estimated periods of disability than males, even after adjusting for initial hospitalization [26,27]. Another study, examining the severity of injury, using workers' compensation data, also reported a higher injury rate for females than males (221 vs. 178 per 10,000 employees per year) [28].However, studies among bus operators have usually excluded

Table 5
Unintentional crude injury rates and adjusted hazard ratios by operator characteristics and work exposures: metropolitan bus operator study, 2006–2011

Personal characteristics and exposures	Total hours (×10,000)	Estimated crude rate	95% CI	Estimated adjusted HR	95% CI
Total	1244.5	17.8	16.1–19.7		
Gender					
Female	248.1	34.6	29.7–40.3	2.4	2.0–2.8
Male	996.4	13.8	12.2–15.7	1.0	—
Age (years)					
< 30	65.1	12.6	8.4–18.9	0.7	0.5–1.1
30 to <40	10.9	14.6	11.2–19.1	0.7	0.5–1.1
40 to <50	363.0	17.8	15.0–21.0	0.9	0.7–1.2
50 to <60	465.0	18.6	16.2–21.4	0.9	0.7–1.2
60 +	170.5	21.3	16.6–27.4	1.0	—
Work Years*					
0 to <5	38.8	14.5	12.2–17.1	0.6	0.5–0.8
5 to < 10	322.1	19.3	16.5–22.6	1.0	0.8–1.2
10 to <15	21.2	18.8	15.6–22.6	1.0	0.8–1.2
≥ 15	322.4	20.3	16.8–24.5	1.0	—
Job classification†					
Full-time	999.9	18.3	16.5–20.4	1.0	—
Part-time	244.6	15.8	13.2–19.0	0.6	0.5–0.7
Operator type†					
Full-time 8 hours	697.9	19.1	16.9–21.5	1.0	—
Full-time 9 hours	152.7	15.0	12.2–18.4	0.8	0.6–1.0
Full-time 10 hours	149.3	18.6	14.8–23.4	1.1	0.8–1.4
Weekday part-time	217.1	16.5	13.6–20.1	0.5	0.4–0.7
Weekend part-time	27.4	11.8	6.9–20.3	0.6	0.4–1.0
Work start time‡					
12 AM to <3 AM	7.3	15.1	6.0–38.3	1.2	0.6–2.6
3 AM to <6 AM	464.6	18.4	15.9–21.1	1.2	0.9–1.5
6 AM to <9 AM	32.9	18.7	16.2–21.7	1.1	0.9–1.4
9 AM to <12 PM	119.1	15.8	12.6–19.9	1.0	—
12 PM to <3 PM	189.6	17.5	14.6–20.9	1.1	0.8–1.4
3 PM to <6 PM	129.1	16.0	12.9–19.8	1.0	0.7–1.3
6 PM to <9 PM	4.3	15.5	5.9–40.8	0.8	0.3–2.6
9 PM to <12 AM	1.9	8.9	0.8–101.4	0.7	0.1–4.8
Weekday§					
Sunday	77.1	10.8	7.7–15.2	1.0	—
Monday	207.2	21.2	18.2–24.7	0.1	0.0–0.4
Tuesday	214.2	19.5	16.6–23.0	0.9	0.2–4.6
Wednesday	214.5	18.6	15.5–22.2	0.8	0.2–4.2
Thursday	211.7	16.5	13.7–19.9	0.2	0.1–0.9
Friday	210.7	17.2	20.8–20.2	0.4	0.1–1.4
Saturday	109.1	16.0	12.6–20.2	0.2	0.1–0.5
Working hours per day‖					
>0 to less than 7 hours	206.6	50.4	44.2–57.5	4.6	3.8–5.5
7 to < 12 hours	1008.1	14.2	12.6–16.0	1.0	—
≥12 hours	29.8	12.4	7.8–19.7	1.4	0.9–2.2
Driving hours per day‖					
0 hours	5.6	7.6	1.5–37.9	0.0	0.0–0.0
>0 to < 7 hours	245.1	41.2	36.2–46.8	3.2	2.7–3.8
7 to < 12 hours	970.8	14.3	12.7–16.1	1.0	—
≥12 hours	23.0	14	8.6–22.9	1.6	1.0–2.5
Overtime hours per day‖					
0 hours	1105.2	18.3	16.5–20.2	1.0	—
>0 to less than 3 hours	59.5	19.6	14.5–26.6	1.1	0.8–1.4
3 to less than 6 hours	37.9	15.5	10.6–22.6	0.9	0.7–1.3
≥6 hours	41.9	5.6	3.0–10.3	0.4	0.2–0.7
Shift§					
Straight	913.3	16.9	15.1–19.0	1.0	—
Split	331.2	20.3	17.6–23.3	1.2	1.0–1.4
Number of routes driven per day¶					
None	5.6	7.1	1.3–39.9	0.4	0.1–1.3
One route	472.4	21.7	19.3–24.5	1.0	—
Two routes	412.1	16.4	14.2–19.0	0.7	0.6–0.9
More than three routes	354.4	15.2	13.0–17.8	0.7	0.6–0.8
Route type¶					
Non	5.5	7.1	1.2–40.7	0.5	0.2–1.5
Regular bus only	619.6	17.9	15.9–20.2	1.0	—
Limited stop only	33.3	28.6	21.0–38.8	1.4	1.0–1.8
Express bus only	98.1	23.5	19.1–29.1	1.0	0.8–1.3
Multiple route type	426.4	16.5	14.3–19.2	0.9	0.7–1.0
Unknown type	61.6	14.8	10.5–20.8	0.7	0.5–0.9

* Adjusted for age and gender.
† Adjusted for age, gender, and work years.
‡ Adjusted for age, gender, work years, job classification, work shift, and garage.
§ Adjusted for age, gender, work years, and job classification.
‖ Adjusted for age, gender, work years, job classification, number route of driving, and route type.
¶ Adjusted for age, gender, work years, job classification, bus garage, work start time, and weekday.

females in their analysis due to small numbers [4,29–31]. Further study is needed relevant to gender exposure differences among bus operators and associated work-related injury experiences.

Long working hours have also been associated with higher risk of work-related injury [9,32–34]. However, the present study found increased risks for those operators who worked or drove less than 7 hours, compared to more than seven and less than 12 hours. This difference is likely due to factors controlled for in the multivariable model, established a priori – and are primary variables that would directly affect bus operators' schedules and working times.

Because metropolitan buses are in operation from early morning to late night, bus operators usually work in shifts. Several previous studies [32,33,35,36] indicated that rotating and irregular work shifts were associated with increased injury risks. From similar findings, in the present study, higher risk was found among bus operators who worked split versus straight shifts. Working experience was also an important covariate that affected work-related injury. Present study results suggested that operators who worked less than five, compared to 15 or more years, had 40% less risk. Similarly, bus operators who had greater driving years would be expected to have higher risk [11,29,37]. From a study investigating vibration exposure among bus operators, those with longer driving experiences had longer-term exposures to whole body vibration (with more than 4.5 years m^2 s^{-4} total vibration dose), resulting in higher risks for all types of lower back pain symptoms and disc protrusion compared to those with no exposure to whole body vibration, such as mechanics, electricians, and general operators [11].

Decreased risks were identified in this study for working part-time versus full-time, in particular weekday part-time, compared to full-time eight-hour shifts—a finding in contrast to some studies reporting that temporary or part-time employees were at higher risk of occupational injuries [38–40].This could be explained by the different classifications of part-time bus operators in the present study population that were adjusted for in the multivariable analysis. In this transit company, all new bus operators commenced with the company as part-time operators; after 12 months, they could apply for full-time positions—an approach that enabled a probationary period for monitored training and gradual increase in experience.

Two factors not investigated previously, in other studies, were the number and types of routes driven by bus operators per day. Results of the present study suggested that those operators who drove more than two routes, compared with only one route per day, had decreased risks; in addition, operators who drove limited stop versus regular routes, had an increased risk of injury.

Strengths and limitations

The strength of this study included the ability to obtain daily working schedules, shifts, and driving information for all bus operators over a 5-year period. By linking an injury reporting system to a work scheduling system, the final data set provided complete working information for each operator's working day, including any days of injury. Although the operators' working shifts and schedules could have changed day-to-day, based on their driving assignments, this longitudinal data set minimized bias due to varying work exposures among bus operators.

This study utilized available company records from a metropolitan transit company. Therefore, some information such as wages, occupational history, personal medical information, physical activities, fatigue status, and sleep hours were not available. Wages may be affected by a number of variables, including length of employment [41]. The number of working years was controlled for in the model to minimize this potential effect. In addition, although the exposures regarding difficulty of the routes driven were not specifically available from company records, exposures relevant to the number of routes driven per day and the route types were examined; further, examination of these exposures included controlling for the bus garage from which each route emanated and, by virtue of their geographical location, are representative of the variations in route difficulties. These factors had not been investigated previously. Potential selection bias could have occurred if employees chose to not report any injury or employees left the company after the injury. Therefore, one of the potential selection biases is the healthy worker effect (HWE). The HWE is a phenomenon that should be considered in any occupational study. Some study results have suggested that the HWE would eliminate 20% to 30% of the association between exposure and outcome [42]. In the present study, although relevant injury data were collected, based on self-reported information, potential biases were minimized, to some degree, through utilization of the longitudinal observations for a 5-year period that were collected directly from the transit company. As identified in the Methods Section, the assumption was that a subsequent injury event was not related to any previous injury event within any bus operator. The bias due to this assumption is limited since the majority of bus operators (55%) reported only one injury during the total period of study. Also, because of the rigid work requirements for bus operators, it is expected that the effects of injury on work duties following any time away from work were minimized. Possible changes in work duties after injury were captured in real-time and used to test for associations with subsequent injury events using the Cox regression models. In addition, the magnitude of injury was estimated by controlling for potential confounding factors and adapting specific statistical models to fit the natural correlated structure of the data set.

Another potential limitation was the lack of information on days away from work, following injury; therefore, it was not possible to estimate severity of the occupational injuries. One prior study compared the age-standardized hospital admission ratios between male operators of passenger transport vehicles and those of goods vehicles in Denmark; it was reported that passenger transport vehicle operators had much lower rates of injuries [30] and that most of the injuries did not require hospital admission. However, lost time from work and restricted activity due to injuries, not involving hospitalization, has also been shown to be an important measure of severity [43–45].

It is important to note that the use of DAGs for development of analytic models, including the selection of confounders, is one of the most recent approaches [17,22,23], applied to numerous epidemiologic study analyses; this approach identifies parsimonious models and excludes covariates that should not be entered into the regression lest they introduce bias [23]. However, the application of DAGs has not, necessarily, been widely accepted or uniformly embraced among many disciplines.

Conclusions

The results of this study identified several risk factors likely to affect the occurrence of work-related injury among urban metropolitan bus operators. Although this effort may not be generalizable to all metropolitan transit systems, these factors can potentially inform the development of targeted intervention strategies, such as working schedule or shift design, to reduce work-related unintentional injuries relevant to bus operators.

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