The Effects of Urban Bus Driving on Blood Pressure and Musculoskeletal Problems: A Quasi-Experimental Study

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Objective: Work settings with high levels of stress are consistently associated with poor health outcomes. This study examines the longitudinal relationships between the number of hours of driving a bus in a city and blood pressure and musculoskeletal problems. **Methods:** A prospective longitudinal design coupled with multilevel random coefficient modeling was used to examine the relationship among exposure to a job with high level of stress, urban bus driving, blood pressure, and musculoskeletal problems. Baseline blood pressure and musculoskeletal symptoms of men and women (n = 88) were assessed before they began driving a bus in central Stockholm. The number of hours of driving per week, blood pressure, and musculoskeletal symptoms were tracked for a period of 5 years. Multilevel random coefficient modeling techniques were used to model how individual trajectories of health effects were affected by the number of hours of driving, after statistically controlling for baseline preworking health measures. **Results:** Controlling for sex and baseline health outcomes, the average number of hours of bus driving per week predicted higher diastolic blood pressure (B = 0.069, standard error = 0.034, p = .042) and more frequent musculoskeletal symptoms (B = 0.013, standard error = 0.003, p < .001). **Conclusions:** The findings provide evidence for a positive association between the number of hours of bus driving and blood pressure and musculoskeletal problems. These findings are discussed in exposures to potentially toxic physical and psychosocial work-related factors. **Key words:** stress exposure, blood pressure, musculoskeletal symptoms.

MRCM = multilevel random coefficient modeling; **ICC** = intraclass correlation coefficient.

INTRODUCTION

Work settings provide a valuable context in the search for identifying mechanisms linking the psychosocial and physical environment to health. Fairly large groups of individuals exposed to identical or similar work conditions can be identified, whereas the impact of factors such as employer policies, organizational culture, and so on can be minimized. Urban bus drivers relative to individuals in similar occupations die at an earlier age, have elevated blood pressure and musculoskeletal problems, retire prematurely with disabilities, have high rates of absenteeism, and report high levels of job stress (1–9). Similar findings have been reported from cities around the world and across race, ethnicity, and sex (3). This study is the first to examine a dose-response reaction between the amount of bus driving and the aspects of physical health. Data presented herein are also unique because individual workers were monitored before the onset of employment and were followed up for several years. We tracked the number of hours per week driving a bus and recorded health indicators during the corresponding periods. This research design enabled us to examine over time, with each driver as her/his own control and independently of prework health levels, the association between the number of hours driving a bus and blood pressure and musculoskeletal problems. These are the two most common health correlates in the bus driving epidemiological literature.

Urban bus driving is a fascinating context in which to study job stress because of the constellation of potentially toxic physical and social characteristics of this work environment. Urban bus drivers routinely contend with a host of physical hazards, known to be health threatening, including toxins, noise, marked temperature fluctuations, and challenging ergonomic conditions from repetitive tasks while sitting for long periods (2,3). Simultaneously, bus drivers work under relentless time pressure often coupled with conflicting demands posed by traffic congestion, maintaining driving safety, and the provision of courteous service to the public. Short of a traffic accident, a bus driver's primary personnel liability is lateness (2,5,10).

Based on the large and consistent body of epidemiological data on bus driver health, we hypothesized that the more hours an individual drives a city bus, the greater the elevation of blood pressure and the frequency of musculoskeletal symptoms. We examined this hypothesis with multilevel random coefficient modeling (MRCM) in a prospective longitudinal design that enabled us to model individual trajectories during the course of 5 years. Because we recruited drivers before employment, we were also able to statistically control for preemployment indices of the same health outcomes.

METHODS

Procedures and Measures

Eighty-eight bus drivers in a central public transit garage in Stockholm, Sweden, (88% men, mean age = 38.6 years) were recruited before their training as a bus driver. Data were collected during a 5-year period. Baseline predriving data were collected during a 3-week training course before the onset of driving. In monthly 10-minute telephone interviews, data were obtained on the number of hours worked in the prior week. At 6-month intervals, health data were collected on blood pressure and musculoskeletal symptoms. A preemployment health and background data collection session occurred in 2001 and was followed by three health outcome follow-ups between 2001 and 2002 and four follow-ups between 2004 and 2006. At each 6-month health monitoring session, blood pressure was measured three times during the course of 20-minute

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TABLE 1. Descriptive Statistics (n = 88)

Variables	M	SD	Min	Max
Age at the start of the study, y	32.80	9.95	21	60
Sex (female = 1, male = 0)	0.14	0.35	0	1
Bus driving exposure, h/wk	22.92	15.46	0	51
Systolic blood pressure, mm Hg	123.00	12.12	93.67	155.33
Diastolic blood pressure, mm Hg	77.26	8.88	56.67	105.68
Musculoskeletal problems	1.33	0.89	0	4

M = mean; SD = standard deviation; min = minimum; max = maximum.

intervals in a session during nonworking hours. The driver was seated, and the average of the last two measures obtained by a fully automatic oscillometric monitor (Omron 705CP, Kyoto, Japan) was used as the index of resting blood pressure. Musculoskeletal measures asked the driver to rate their symptoms from 0 = *never* to 4 = *constantly* on a four-item version (α = 0.78) on a standardized musculoskeletal difficulties index (11). A sample item was "Did you, in the last six months, experience low back pain." Validity for this index varies from 100% to 87% agreement between the individual's self reported musculoskeletal symptoms and a complete medical history conducted by a trained physiotherapist (11).

The study was approved by the ethics committee of the Swedish Council for Working Life and Social Research.

Data Analysis Strategy

Bus driving exposure was measured in each telephone interview as the number of hours worked in the past week. Because we were interested in predicting subsequent health outcomes from bus driving exposure, we averaged the number of hours driving a bus per week from all available telephone interviews (varying between two and five) taken before each biannual assessment of blood pressure and musculoskeletal difficulties. Our models consider bus driving exposure in one wave as a predictor of health outcomes in the subsequent wave of the study, controlling for levels of each health outcome at baseline (before beginning work as a bus driver). The control variables for prework health were grand-mean centered. This enables meaningful interpretation of the intercept.

MRCM was used to test our hypothesis that the amount of bus driving is related to blood pressure and musculoskeletal symptoms. MRCM allows for the simultaneous estimation of within- and between-person effects (12). At Level 1, outcomes are estimated as a function of time and time-varying covariates, and at Level 2 variability in the Level 1, coefficients are modeled as a function of person-level, time-invariant covariates. Because exposure to bus driving was measured at each wave of data collection for the same person, it was included in the model as a Level 1 predictor. In addition, linear and quadratic time parameters were included at Level 1 to control for time-related trends in physical health that would be expected to occur regardless of bus driving.

At Level 2, variance in the intercept was modeled as a function of person-level variables. The effects of baseline health, assessed before the onset of bus driving exposure, were statistically controlled in all models. Sex was also included to adjust for its known association with health outcomes. Age was not included because age-related trends were accounted for by controlling for time.

On average, participants had complete data for 2.3 of a possible 5 occasions. Although there were seven waves of data collected, because the current analysis uses a lagged variable for bus driving exposure, each driver had five possible Level 1 data points. Missing data at Level 1 were significantly correlated with average exposure to bus driving across waves (r = 0.37, p < .001), suggesting that those who drove more were less likely to be absent from data collection. It is possible that this could bias the results. However, because those who drove less are underrepresented in these data, this likely decreased variance in exposure and therefore would yield more conservative estimates. Aside from potential problems with nonrandomness, missing data at Level 1 in MRCM do not cause problems for parameter estimation (12).

RESULTS

Descriptive data on the sample and all of the health outcomes are depicted in Table 1. Note that data on sex are based on 88 participants, whereas all other data are calculated across the multiple waves of data analysis.

To obtain the variance components necessary to calculate intraclass correlation coefficients (ICCs), unconditional (null) models were initially estimated for each outcome variable. Having established null models, full models were then estimated to determine the effects of bus driving exposure on health. Table 2 shows the null and full models for each outcome.

The ICC is calculated from the null models by dividing the between-person (intercept) variance by the total variance. For systolic blood pressure, the ICC was 0.63. This suggests

TABLE 2. Multilevel Model Estimates for Systolic Blood Pressure, Diastolic Blood Pressure, and Musculoskeletal Problems

	Systolic Blood Pressure		Diastolic Blood Pressure		Musculoskeletal Problems	
	Null Model	Full Model	Null Model	Full Model	Null Model	Full Model
Variables	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Level 1 (N = 200)						
Intercept	122.44 (1.18)***	122.16 (1.45)***	77.56 (0.875)***	75.57 (1.16)***	1.32 (0.084)***	0.927 (0.100)**
Bus driving exposure		0.055 (0.051)		0.069 (0.034)*		0.013 (0.003)***
Time		0.697 (1.21)		1.30 (0.77)		0.128 (0.076)
Time squared		−0.075 (0.166)		−0.139 (0.101)		−0.015 (0.010)
Level 2 (n = 88) (intercept predictors)						
Prior levels of outcome		0.597 (0.071)***		0.572 (0.094)***		0.578 (0.092)***
Sex (female)		−6.24 (2.58)*		−3.72 (2.22)		0.327 (0.225)
Variance components						
Intercept	104.89***	34.09***	58.06***	31.95***	0.540***	0.232***
Residual	61.51	53.91	32.16	25.91	0.275	0.296

Prior levels of outcome are grand-mean centered in each model. All other variables are uncentered.
* p < .05, ** p < .01, *** p < .001. Levels of significance for intercept variance components were calculated using the likelihood ratio test (12).

that the remaining 37% of the total variability in systolic blood pressure can be accounted for by within-person changes across time. For diastolic blood pressure, the ICC was 0.64, and for musculoskeletal problems, the ICC was 0.67. Thus, within-person measures of health showed sufficient variability to allow the possibility of modeling predictors of within-person relationships.

Full models were then estimated to test these effects. For two of the three health outcomes, individual variations in exposure to bus driving were significantly associated with changes in physical health. Specifically, parameter estimates from Table 2 show that bus driving exposure predicts higher levels of diastolic blood pressure ($B = 0.069$, standard error [SE] = 0.034, $p = .042$, 95% confidence interval [CI] = 0.002–0.136). These effects are shown in Figure 1. Greater exposure to bus driving also elevates the frequency of musculoskeletal problems ($B = 0.013$, SE = 0.003, $p < .001$, 95% CI = 0.007–0.020; Fig. 2). Systolic blood pressure, however, was relatively unaffected by the extent of bus driving ($B = 0.055$, SE = 0.051, $p = .281$, 95% CI = −0.045 to 0.155).

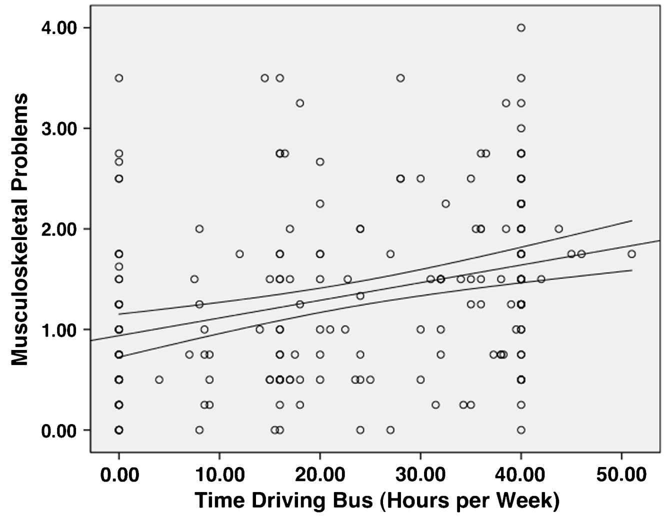

Figure 2. Fitted line plot depicting the relationship between bus driving exposure and subsequent musculoskeletal problems. This figure is based on parameter estimates from the model presented in Table 2. Thus, statistical controls for levels of musculoskeletal problems measured before driving a bus and sex are included.

DISCUSSION

Several occupations, including urban bus driving, have been associated with serious health problems. The findings of occupational medicine and environmental epidemiology are challenged, however, by the threat to internal validity of selection bias. The putative effects of working conditions on health usually cannot be disentangled from the characteristics of persons working under the environmental conditions believed to be causing health problems. The ideal solution to this conundrum is the true experiment wherein one randomly assigns individuals to different working conditions. Another strategy but one fraught with difficulties is a laboratory simulation wherein one randomly manipulates exposure to well-controlled environmental exposures representative of the characteristics of work thought to produce ill health. The first solution to the selection problem is nearly impossible, and the second one suffers from its own serious inferential problems. The validity of generalizing from short-term artificial work exposures with voluntary compliance (as typically required by ethical boards) to real work environmental exposures is questionable. This type of experimental work also tends to isolate one aspect of the salient components of the work setting (e.g., noise levels), whereas in reality, many unhealthy occupations encompass multiple health risks, as in the case of urban bus driving (e.g., time pressure in conjunction with traffic congestion). In the present program of research on urban bus driving and health, we have pursued a middle ground using real-world exposure to working conditions coupled with a rigorous research design and statistical methods that allow the description of a dose-response relationship between exposure to bus driving and aspects of physical health that is independent of preemployment health symptoms. We monitored urban bus drivers before they began driving a bus and then during a 5-year period.

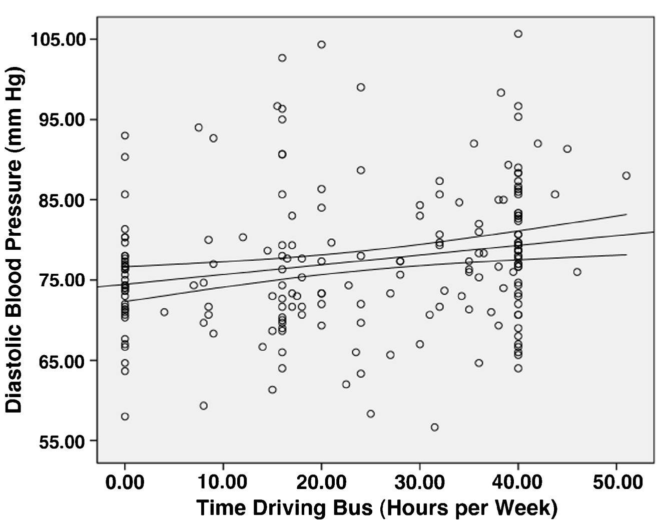

Figure 1. Fitted line plot depicting the relationship between bus driving exposure and subsequent diastolic blood pressure. This figure is based on parameter estimates from the model presented in Table 2. Thus, statistical controls for sex and levels of diastolic blood pressure measured before driving a bus are included.

As shown in Figures 1 and 2, the more hours a person drives a bus in the city, the higher their diastolic blood pressure and the worse their musculoskeletal symptoms. These effects are significant (Table 2) after statistically controlling for baseline levels of each respective health outcome before becoming a bus driver. These findings strengthen current occupational health studies that have shown associations between operating a bus in an urban setting and adverse health outcomes (1–9).

Moreover, the findings likely underestimate the true negative health effects of working as a bus driver in an urban setting for several reasons. First, individuals who drive buses less are underrepresented in the data, thus downwardly biasing parameter estimates. Second, job applicants who are less healthy (e.g., hypertensive, preexisting musculoskeletal difficulties) are eliminated from the employment pool by preemployment screening conducted by Busslink, the Stockholm transit company. Only healthy relatively young adults were in the initial cohort of prospective drivers. Third, we monitored these new, young drivers for only a relatively short portion of their working life, 5 years. Fourth, we simply compared the number of hours worked as a driver per week with the health outcomes. This does not take into account fluctuations in the psychosocial (e.g., time pressure, decision latitude) and physical (e.g., traffic congestion, noise) characteristics of the work setting of urban bus drivers that are believed to produce adverse health effects. Such unspecified variability within driving duration would also downwardly bias our parameter estimates. Finally, a few of the drivers switched from city driving to driving in less stressful suburban driving during the study period, which would lead to underestimation of negative health effects.

The present findings provide the strongest evidence to date that driving a bus in the city is unhealthy. The more hours one drives a bus, the worse one's health. Our data converge with a large number of cross-sectional occupational epidemiological studies showing that urban bus drivers, relative to persons of similar backgrounds in other blue-collar jobs, have higher rates of hypertension, cardiovascular disease, and elevated blood pressure and frequency of musculoskeletal problems (1–5,7–9). Urban bus driving is believed to be unhealthy because of the high levels of stress engendered by the array of adverse physical and psychosocial conditions typically accompanying bus driver operation in cities. Many of these conditions in their own right (e.g., noise, traffic congestion, time pressure, low level of job control) have been linked to both psychological and physiological indices of stress (2,3,5,10).

Another fascinating aspect of the urban bus driving context is the distinct possibility that this occupation is health threatening because of drivers' exposure to an accumulation of multiple physical and psychosocial demands. Several other occupations associated with high rates of morbidity and premature retirement (e.g., police officer, firefighter) may share these characteristics of cumulative stressor exposure. Interesting parallels exist in child psychiatry and psychology wherein young children exposed to single, even extremely traumatic events, typically emerged unscathed, whereas those exposed to cumulative risks often manifest physical (13) and psychological pathologic condition (14).

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