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Not Just an Ache: Examining the Rate of Musculoskeletal Pain in City Bus Drivers

Jeremy Steele

MINETA TRANSPORTATION INSTITUTE

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NOT JUST AN ACHE: EXAMINING THE RATE OF MUSCULOSKELETAL PAIN IN CITY BUS DRIVERS

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16. Abstract

This paper examines the rates of musculoskeletal discomfort in a sample of 957 city bus drivers at King County Metro, a public transportation agency serving the greater Seattle area. It also examines how often such pain prevented drivers from doing their normal work, needed treatment from a medical professional, or incited one or more worker's compensation claims. To assess the level of musculoskeletal discomfort in city bus drivers, an anonymous survey was distributed to drivers at King County Metro, a public transportation agency serving the greater Seattle area. This survey consisted of a Nordic Questionnaire asking drivers whether or not they experienced pain in certain areas of the body in the past twelve months, along with a small section asking for basic information such as age, hours per week worked, and gender. The results of the survey demonstrate that bus drivers experience very high rates of musculoskeletal pain, with 85% of respondents indicating pain in at least one area of the body. Comparisons to CDC data show higher rates of musculoskeletal pain in this sample than in the general population. Female and full-time drivers showed consistently higher rates of pain across all areas of the body then their male and part-time counterparts, while variables such as BMI and age showed less influence. Rates of pain in the lower back, shoulders, and knees were especially elevated. Of those experiencing pain in at least one area of the body, more than 50% were prevented from doing their normal work and visited a medical professional. For all drivers experiencing pain, there were large gaps in the rates of medical visits and worker's compensation claims. Policy recommendations include the provision of active-suspension seats in the agency's fleet of buses and better placement of key controls in the drivers' workstation, two goals potentially attainable through increased participation of drivers in the bus-procurement process. The role of different route types, stop placement patterns, and road surfaces in addressing rates of musculoskeletal pain in bus drivers should also be investigated.

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EXECUTIVE SUMMARY

This paper examines the rates of musculoskeletal discomfort in a sample of 957 city bus drivers at King County Metro, a public transportation agency serving the greater Seattle area. It also examines how often such pain prevented drivers from doing their normal work, needed treatment from a medical professional, or incited one or more worker's compensation claims. To assess the level of musculoskeletal discomfort in city bus drivers, an anonymous survey was distributed to drivers at King County Metro, a public transportation agency serving the greater Seattle area. This survey consisted of a Nordic Questionnaire asking drivers whether or not they experienced pain in certain areas of the body in the past twelve months, along with a small section asking for basic information such as age, hours per week worked, and gender. The results of the survey demonstrate that bus drivers experience very high rates of musculoskeletal pain, with 85% of respondents indicating pain in at least one area of the body. Comparisons to CDC data show higher rates of musculoskeletal pain in this sample than in the general population. Female and full-time drivers showed consistently higher rates of pain across all areas of the body then their male and part-time counterparts, while variables such as BMI and age showed less influence. Rates of pain in the lower back, shoulders, and knees were especially elevated. Of those experiencing pain in at least one area of the body, more than 50% were prevented from doing their normal work and visited a medical professional. For all drivers experiencing pain, there were large gaps in the rates of medical visits and worker's compensation claims. Policy recommendations include the provision of active-suspension seats in the agency's fleet of buses and better placement of key controls in the drivers' workstation, two goals potentially attainable through increased participation of drivers in the bus-procurement process. The role of different route types, stop placement patterns, and road surfaces in addressing rates of musculoskeletal pain in bus drivers should also be investigated.

I. INTRODUCTION

Musculoskeletal discomfort—and especially low back pain, shoulder pain, and neck pain—has been studied consistently in a variety of occupational environments and shown to be a persistent health issue in many of them. City bus operators are not an exception. On top of high job demands and other issues more commonly associated with the occupation, musculoskeletal disorders (MSDs), i.e. pain or injuries affecting the musculoskeletal system, have repeatedly been established as a significant problem for bus drivers.

This study examines rates of musculoskeletal discomfort in a large population of bus operators working for King County Metro, a transit agency serving King County, Washington. Most notably, this county is home to the rapidly expanding cities of Seattle and Bellevue. Seattle buses and King County Metro drivers have been the subjects of recent investigations in the literature regarding the bus fleet itself. This research, summarized later in the report, focuses on the whole-body vibrations felt by bus operators while driving their routes, which have been found to have a negative impact on drivers' health. The present study builds on existing literature by examining the health outcomes for the operators. Specifically, it attempts to answer the following questions:

1. What are the rates of musculoskeletal pain in bus drivers? Do work-related and/or sociodemographic factors significantly influence these rates? Do drivers experience higher rates of musculoskeletal pain than the general population?

2. Of those drivers experiencing musculoskeletal pain, how many are prevented from doing their normal work, and how many have looked for further assistance? Do these rates also vary depending on work and/or sociodemographic factors?

Recent years have seen considerable expansion in the bus services offered by King County Metro as demand for alternative modes of transportation continues to increase in the area. With this expansion, King County Metro has had to rapidly enlarge its fleet of vehicles to meet demand. Results from this report, then, have strong relevance to the procurement of new vehicles, and will allow the agency to better design vehicles to suit drivers' needs.

In this report, a literature review summarizes existing studies outlining specific areas of the body found to be particularly aggravated in populations of occupational drivers, also looking at broader research on bus drivers' health. Next, the methodology of the survey is laid out, explaining the design of the survey and its embedded Nordic questionnaire handed out to participants. A results section summarizes the findings from the survey. The discussion attempts to answer each of the research goals in detail and compares the rates of musculoskeletal pain from this survey to existing CDC data. The findings of this report are summarized in the conclusion, along with suggestions for future research and policy implications.

II. LITERATURE REVIEW

Past studies on bus drivers' health, and particularly on occupation-related musculoskeletal disorders, have focused on sociodemographic characteristics and existing health conditions of bus drivers as explanatory variables for differences in pain and injury. The Nordic Musculoskeletal Questionnaire is a common tool in such research, as it has been referred to as being "repeatable, sensitive and useful," with "acceptable" reliability and a focus on symptoms most frequently found in occupational settings.[1] Further studies have employed control populations and generally agree that occupational drivers of buses, trucks, and other vehicles incur higher rates of pain and injury compared to non-driving occupations.

The following section provides an overview of the existing research investigating different aspects of bus drivers' health, well-being, and safety. It first summarizes the relevant research on musculoskeletal disorders (MSDs), broken down by the effects of gender, hours per week, and age on its prevalence. It then summarizes research completed on other health issues commonly faced by bus and other occupational drivers. Lastly, it underlines the policy recommendations made by existing literature.

MUSCULOSKELETAL PAIN

Research has consistently shown that bus drivers experience higher levels of MSDs than both the general population and other employees at transit agencies. Netterstrom and Juel investigate the prevalence of low-back pain in 2,045 male bus drivers in Denmark, finding that it is significantly higher than that among the study's control group.[2] Bovenzi and Zadini investigate low-back pain symptoms in both bus drivers and a control group of maintenance workers in Trieste, Italy; they find significantly higher rates of both lower-back and other pain in bus drivers compared to the control population.[3] Similarly, a study of 195 subjects in a California urban transit union found a 30% difference in the amount of back or neck pain experienced by motor coach drivers and non-drivers.[4]

Recent literature has specifically focused on high exposure to whole-body vibrations (WBVs) as a potential explanation for musculoskeletal disorders in bus drivers. A comparative study between Swedish and American bus drivers by Magnusson et al. finds that WBV exposure is a significant risk factor for musculoskeletal disorders.[5] A measurement of vibration levels in Seattle buses on test routes traversing various road conditions by Lewis and Johnson concludes that they are well above recommended amounts.[6] A somewhat similar study by Jonsson et al. evaluates the vibration-suppressing performance of an air-suspension seat versus a static seat in both low-floor and high-floor buses. They find that the air-suspension seat provides little added absorbency from the WBVs.[7] Relatedly, Thamsuwan et al. compare high-floor and low-floor vehicles in terms of driver exposure to WBVs, but unlike Jonsson et al., they recommend a further review of the seat's role in reducing drivers' WBV exposure.[8] Blood et al. further examine the role of three different seats with varying foam types and seat pressures in driver exposure to WBVs, using a similar methodology. Much like Jonsson et al., they find that no seat was the out-and-out best performer and that WBVs remained a significant issue.[9]

Gender

Although most existing research on MSDs in bus drivers comes from a male-heavy or male-exclusive pool of respondents, some existing research shows that, among bus drivers, women are more likely to develop MSDs than men. This finding is most strongly stated in a study by Wei et al. of 2,095 metropolitan Minnesota bus operators. They found that female workers were at higher risk for developing work-related injuries.[10] It is, however, important to note that the literature examining the role of gender in the prevalence of MSDs in bus drivers is very limited when compared to research on the role of other factors, such as hours per week, age, and stress-coping mechanisms.

Hours per Week and Shift Types

Research also shows that the schedules and shift types of drivers influence both driver fatigue and musculoskeletal pain. A study by Tamrin et al. found that rates of musculoskeletal disorders was much higher in those driving more than eight hours daily than others.[11] One counterpoint to this is a study by Akinpelu et al., which does not find a significant relationship between hours worked and MSDs. However, even the authors of the study underline the peculiarity of that finding in the context of previous research.[12]

Age and Seniority

Existing studies have shown that age is also an important explanatory variable for MSDs. Szeto and Lam use the Nordic questionnaire to evaluate rates of MSDs in 481 Hong Kong bus drivers, finding that younger age groups actually have higher prevalence of pain. They refer to this phenomenon as the "survivor bias."[13] A study by Alperovitch-Najenson et al. of bus drivers in Tel Aviv focusing solely on low-back pain found a similar pattern, which they termed the "healthy worker effect." They theorized that high levels of injury in the occupation tend to force drivers to retire or find other employment due to the high prevalence of MSDs, inflating injury rates for younger drivers.[14] The healthy worker effect is also discussed in a literature review of epidemiological studies on bus drivers by Winkleby et al., which, like much of the aforementioned literature, emphasizes the abnormally high rates of MSDs in bus drivers.[15]

OTHER HEALTH ISSUES

A sizable amount of studies on occupational stress on bus drivers reveals not only that stress is a major problem in the occupation, but also that it can negatively affect other aspects of drivers' health as well, including musculoskeletal issues. Using a sample of 60 Los Angeles-area bus drivers, Evans and Carrere find in a 1991 study that traffic congestion plays an important role as a stressor for bus drivers.[16] A study of 1,396 San Francisco bus operators by Albright et al. finds inverse relationships between job demands, job strain, and hypertension.[17] Aronsson and Rissler find that bus drivers' reported stress levels during work sessions far surpassed those during comparison sessions.[18] Bartone's 1998 study of 912 Chicago bus drivers finds a moderately strong correlation between stress and illness, with a focus on regressive coping tendencies as a linking variable between the two.[19] A more recent paper by Kontogiannis further investigates drivers' stress coping mechanisms

and their relation to aberrant driving behavior, associating confrontational responses with unsafe conduct.[20] Similar studies by Cendales et al., Useche et al., and Montoro et al. evaluate bus drivers' responses to stress and their relation to job strain and risky driving behavior.[21] Similarly, Chen and Kao focus on job burnout and its association with drivers' stress, finding strong relationships between job strain, burnout, health problems (such as musculoskeletal issues), and aberrant driving behavior.[22] The above studies commonly underline a strong positive relationship between drivers' stress and health problems, such as musculoskeletal issues.

Job fatigue and sleepiness have also been underlined as a major issue for bus drivers, and, like stress, have been associated with other health issues, including musculoskeletal ones. Although there are no direct links between musculoskeletal issues and sleeping disorders in the extant literature, many related physical health problems have been correlated to fatigue and sleepiness while driving. A study of 2,389 drivers of Japanese buses, subways, or railways by Sasai-Sakuma et al. estimates that sleep-apnea syndrome is prevalent in 9.8% or higher of the respondents who underwent a medical evaluation.[23] Anund et al. employ a different methodology to evaluate sleepiness in a sample of 231 city bus drivers of Stockholm, Sweden. Through a detailed questionnaire, they find that a significant portion of bus drivers have to fight to stay awake while operating their vehicle.[24] Another, more specific paper by Anund et al. makes use of a within-subject design involving 9 male and 9 female bus drivers in Linkoping, Sweden working morning-afternoon split shifts; it reports that the respondents suffered from significant sleepiness and reductions in driving performance during the later shift.[25] Davidovic et al. attempt to identify the factors influencing fatigue among 345 male Serbian bus and truck drivers, finding that both work factors, especially excessive hours, and health factors were important in determining fatigue among the respondents.[26]

IMPLICATIONS FOR AGENCIES

The existing literature consistently recommends agency-level changes in recruitment, training, and work culture as avenues for improving bus drivers' health. Tse et al., through a comprehensive literature review on bus driver well-being, conclude that improvements in both recruitment and job conditions are necessary. They suggest that the recruitment processes used by agencies should better reflect an average day on the job, and that agencies should provide trainings to help drivers cope with stress and unruly riders.[27] Crizzle et al. reflect this conclusion in a similar literature review which also includes long-haul truck drivers, adding that individual-level interventions, such as diet improvements or increased physical activity, are often unsustainable or ineffective, and that change in the occupation must occur at a higher level.[28] A literature review on stress in bus drivers by Kompier and Di Martino recommends long-term, structural changes at transit agencies in order to reduce stress and related health issues in bus drivers.[29]

Better bus procurement and design is one recurring recommendation made to transit agencies in the current literature. A TCRP report investigates the potential for agencies to acquire buses with better operator workstation areas through improved procurement processes.[30] Both Okunribido et al. and Yasobant et al. recommend an investigation of the design of bus drivers' seats and the resulting posture of drivers as an explanation for high

levels of MSDs in drivers.[31] Gregersen examines the cost tradeoffs of three approaches to upgrading King County Metro bus driver seats in Seattle, WA; she estimates that upgrading bus drivers' seats would save the agency money in the long run by reducing the costs incurred by worker's compensation claims.[32]

III. METHODOLOGY

To assess musculoskeletal pain prevalence in King County Metro bus drivers, an anonymous survey with two primary components was distributed to drivers (Appendix A). The first component of the survey asked respondents to answer general demographic questions, including years of seniority (the years worked by the driver at King County Metro), hours per week worked, age, height, weight, part-time or full-time status, and gender. The second and main component of the survey consisted of a Nordic questionnaire which asked whether respondents had felt pain in the following areas over the past 12 months: neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs, knees, and ankles/feet. If a respondent were to answer 'yes' for any area of the body, the survey then prompted the respondent with four follow-up questions: whether or not the pain had prevented them from doing their normal work, whether or not they had felt such pain in the last 7 days, whether or not they had consulted a medical professional for the pain, and whether or not they had applied for worker's compensation for the pain. The questions were presented as a table of 45 yes/no checkboxes with areas of the body as rows and the five corresponding questions as columns.

The survey was handed out during the 'pick,' a biannual procedure whereby drivers choose their schedules for the upcoming service period. The 'pick' lasted from May 13th to May 25th, and surveys were collected on all weekdays during this time. The drivers with more seniority choose earlier, and as a majority of the surveys were handed out and collected during the last three days of the 'pick,' response rates are especially pronounced for drivers with low seniority. The survey targeted all King County Metro drivers, both part-time and full-time. To collect surveys, two researchers, one a former driver at the agency, intercepted drivers as they entered or exited the 'pick' room at King County Metro's Atlantic bus base. All persons in the immediate area were approached and asked to respond (as almost all were drivers), and no explicit refusals to participate in the survey were recorded. In total, 1326 surveys were collected from respondents.

Because of the design of the survey, the responses had to be checked for contradictory answers, which would invalidate them from the final analysis. Survey responses were entered into a spreadsheet, which was then exported to a comma-separated values (.csv) file. A simple Python script was used to check for blank cells or other errors in data entry. Errors were then re-checked against the original surveys. Another Python script was subsequently used to filter out incomplete and incorrectly filled-out surveys (e.g., if the respondent indicated that they had not had pain in a specific area of the body in the past 12 months, but answered 'yes' to one of the follow-up questions). The filtered file was then entered into SPSS, which was used for the data analysis.

IV. RESULTS

The results of the survey are broken down as follows. Firstly, the survey demographics are presented. Next, rates of musculoskeletal pain are displayed, broken down by gender, hours per week worked, age and seniority, and BMI. A logistic regression model combines these factors to analyze their relative influence on musculoskeletal pain. Lastly, rates of work prevention, medical visits, and worker's compensation claims are analyzed, broken down by gender and hours per week worked.

RESPONSE RATES AND DEMOGRAPHICS

In total, 1,326 surveys were collected, of which 957 were completely and non-contradictorily filled out and subsequently used in the data analysis. At the time of data collection, there were 3,003 drivers at the agency, meaning almost one out of every three drivers at the agency is represented in the final sample.[33] Of the 957 survey respondents, 23% identified as female while 77% identified as male. 27% of respondents were part-time workers and the other 73% worked full-time. Given that, at the time data was collected, there were 1,996 full-time drivers and 1,007 part-time drivers, the sample slightly over-represents full-time drivers, but not excessively.[34] Tables 1 and 2 show frequency distributions for the age, seniority, hours per week worked, and the calculated body-mass index (from the height and weight questions in the survey) of respondents.

Table 1. Age and Seniority of Survey Respondents

Age		Seniority	
Age Group	**Frequency (%)**	**Seniority Group**	**Frequency (%)**
< 30	5	< 5	34
30–39	16	5–9	15
40–49	21	10–14	16
50–59	34	15–19	13
60–69	23	20–24	8
70+	2	25–29	5
		30+	9

Table 2. Hours per Week Worked and BMI of Survey Respondents

Hours per Week		BMI	
Hours per Week	**Frequency (%)**	**BMI**	**Frequency (%)**
< 20	10	< 18.5	1
20–39	17	18.5–24.9	18
40–59	67	25–29.9	36
60+	6	30+	44

The mean age of respondents was 51 years, with a standard deviation of 12. For seniority, the mean was 12 years, with a standard deviation of 11. Respondents worked an average of 39 hours per week, with a standard deviation of 13. As for BMI, the average respondent was obese, according to the CDC guidelines, with a mean of 30 and standard deviation of 6. It is important to note that none of these variables appear to be normally distributed, as confirmed by the results of Shapiro-Wilk normality tests on each of these variables, which all reject the null hypothesis of normality at the .01 significance level.

RATES OF MUSCULOSKELETAL PAIN

Table 3 shows the frequency of musculoskeletal pain among the respondents in each of the areas included in the questionnaire. Of all respondents, 85% reported having developed an injury or pain in at least one part of the body in the past 12 months. The most frequently cited areas of the body were the lower back, with 60% reporting pain in the last 12 months, then shoulders, with 51%, then knees, with 47%. The neck area was also a common source of pain, where 46% of respondents reported having discomfort in the last 12 months.

Table 3. Frequency of Musculoskeletal Pain by Body Area

	Right (Last 12 Months)	Left (Last 12 Months)	Both (Last 12 Months)	Total (Last 12 Months)	Total (Last 7 Days)
	Frequency (%)				
Neck	--	--	--	46	23
Shoulders	19	13	19	51	26
Elbows	6	4	6	16	7
Wrists/Hands	10	5	17	32	14
Upper Back	--	--	--	29	14
Lower Back	--	--	--	60	28
Hips/Thighs	16	5	12	33	17
Knees	23	5	18	47	24
Ankles/Feet	12	4	12	28	14
1 or More	--	--	--	85	56

Of note are the disproportionately low frequencies of pain reported exclusively in the left areas of the body. For each body part where respondents were asked whether the pain occurred on the right, the left, or both, rates of pain on just the left side were consistently much lower than those for just the right side and for both.

Rates of pain in the last 7 days mirror the patterns of rates of pain in the last 12 months, but at about half the magnitude. The lower back, shoulders, knees, and neck area remain the areas with the highest rates of discomfort in the 7 days before the survey was distributed.

Differences across Gender

To test for differences in rates of pain across gender, a chi-square difference of proportions test was used to compare respective rates of pain in each area of the body inquired about on the Nordic questionnaire. Table 4 illustrates the results.

Table 4. Rates of Pain, by Body Area, by Gender

	Frequency: Last 12 Months (%)		Frequency: Last 7 Days (%)	
	Male	**Female**	**Male**	**Female**
Neck	41	62**	20	34**
Shoulders	47	64**	22	42**
Elbows	13	23**	5	13**
Wrists/Hands	27	49**	11	24**
Upper Back	25	41**	12	21**
Lower Back	57	69**	25	41**
Hips/Thighs	28	51**	14	34**
Knees	43	61**	21	34**
Ankles/Feet	25	38**	12	24**
1 or More	82	95**	50	78**

** indicates a significant difference between men and women, at $p < .01$.

As indicated in Table 4, rates of pain for each part of the body were significantly higher among women than among men, each at the .01 significance level. This is true for both periods of time inquired about in the survey. Notably, 95% of women reported having pain in at least one area of the body over the last 12 months, versus 81% of men. Further, 78% of women reported pain in at least one area of the body over the past 7 days, versus 50% for men, a difference of 28 percentage points.

Differences across Hours per Week Worked

Similar differences were found between part-time and full-time workers, although they were less pronounced. The same chi-square difference of proportions test was used to determine whether differences in rates of discomfort for each body part were significant. The results are displayed in Table 5.

Table 5. Rates of Pain, by Body Area, by Part-Time/Full-Time

	Frequency: Last 12 Months (%)		Frequency: Last 7 Days (%)	
	Part-Time	**Full-Time**	**Part-Time**	**Full-Time**
Neck	41	**48***	21	24
Shoulders	40	**55****	20	**28***
Elbows	13	17	6	7
Wrists/Hands	25	**34****	11	15
Upper Back	22	**31****	10	**16***
Lower Back	49	**64****	22	**31***
Hips/Thighs	30	34	13	**19***
Knees	41	49	19	**25***
Ankles/Feet	22	**30***	11	16
1 or More	81	**86***	52	58

* indicates significant difference between part-time and full-time at $p < .05$ level.
** indicates significant difference between part-time and full-time at $p < .01$ level.
Bold indicates significant difference between part-time and full-time at $p < .05$ or $p < .01$ level.

For all areas of the body, full-time workers reported higher rates of pain. However, differences are generally less significant than those found between men and women in the study. The larger significance of gender differences compared to differences in hours worked is a surprising result. Also, these differences weaken considerably when the duration of pain is reduced to the frame of 7 days before the survey was administered, where there are no differences that were found to be significant past the .05 confidence level.

Table 6 provides a more in-depth overview of the relationship between hours worked and injury rates, showing injury rates by hours per week worked in twenty-hour groups.

Table 6. Rates of Pain, by Body Area, by Hours per Week Worked

	Respondents with pain in last 12 months (%)			
	< 20 Hours	**20–39 Hours**	**40–59 Hours**	**60+ Hours**
Neck	37	43	48	44
Shoulders	35	43	54	64
Elbows	11	14	17	16
Wrists/Hands	17	28	35	30
Upper Back	19	25	31	30
Lower Back	39	54	64	62
Hips/Thighs	29	30	34	38
Knees	33	46	49	44
Ankles/Feet	23	23	31	26
1 or More	74	85	87	82

Although there is a clearly positive relationship between the two variables, patterns vary between areas of the body. One surprising finding is that rates of pain in the 60+ hours per week group are actually lower than those in the 40–59 hours per week group for most areas of the body, and for those experiencing pain in at least one area. For some areas, such as the lower back, the range of rates of discomfort is very large; for example, there is a 25 percentage point difference in rates of low back pain between the under 20 hours group and the 40–59 hours group.

Differences across Age and Seniority

Figure 1 illustrates differences in rates of pain in the four most-mentioned areas of the body across the seniority variable.

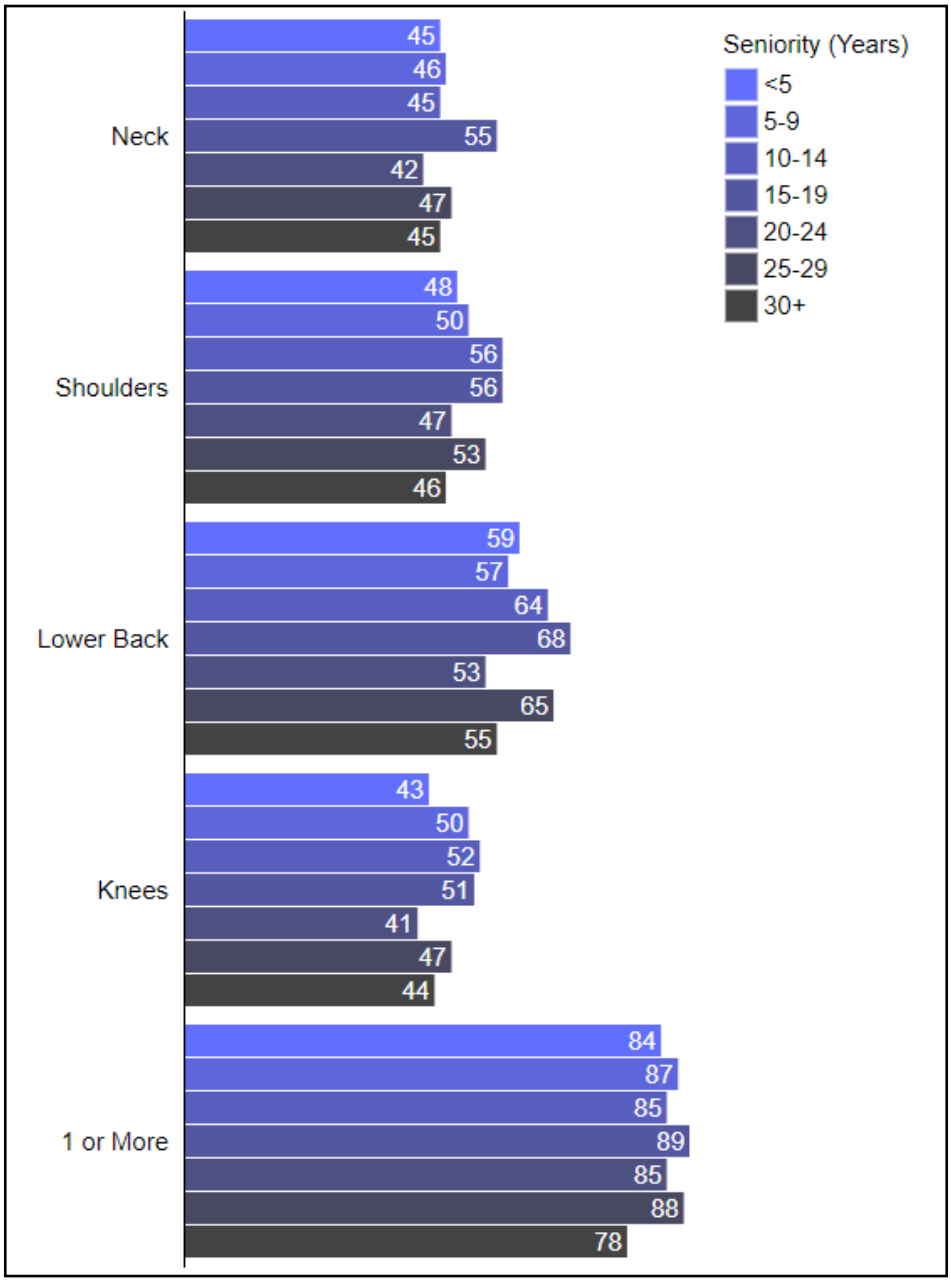


Figure 1. Rates of Pain, by Body Area, by Seniority

It is difficult to discern consistent patterns in rates of pain across the seniority variable. The 20–24 and 30+ year groups show consistently lower rates of pain compared to surrounding groups. However, no overarching pattern is consistent across different areas of the body.

Figure 2 uses a similar illustration and the same areas of the body to examine the effect of age on musculoskeletal pain.

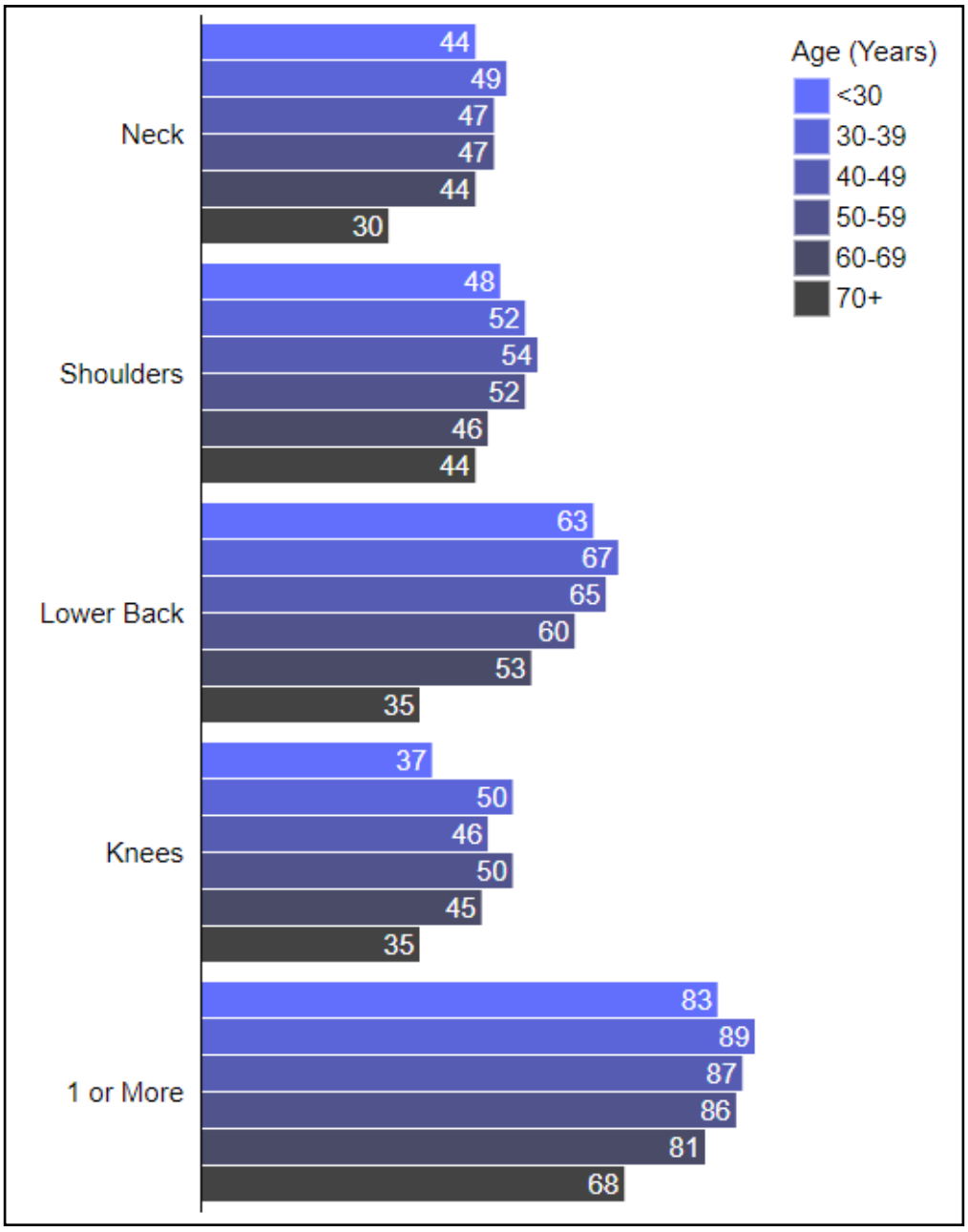


Figure 2. Rates of Pain, by Body Area, by Age

In all areas of the body above, there is a clearer pattern than in Figure 1, where rates of pain reported by drivers decreases at around the 50–59 year age range, and in some cases, such as the lower back, even earlier on. However, it is important to note the small sample size of the 70+ group (22 respondents), which might influence the consistently

very low rates of musculoskeletal pain reported by that group—there is a possibility that it could be a statistical anomaly. Overall, the relationship of pain with age is much more visible than that with seniority.

Differences across Body Mass Index

To assess differences in rates of musculoskeletal discomfort across respondents' body-mass index (BMI), BMI was grouped following the underweight, normal, overweight, and obese classifications used by the CDC. Table 7 best demonstrates the patterns in the data. In all areas of the body, the obese category shows higher rates of musculoskeletal pain, apart from elbows and upper back. As there were only 7 respondents in the underweight category, those results are not interpretable.

Table 7. Rates of Pain, by Body Area, by BMI

	Respondents with pain in last 12 months (%)			
	< 18.5 BMI	**18.5–24.9 BMI**	**25–29.9 BMI**	**30+ BMI**
Neck	43	39	47	49
Shoulders	43	49	49	53
Elbows	29	13	17	16
Wrists/Hands	29	30	29	35
Upper Back	43	29	31	27
Lower Back	57	54	58	65
Hips/Thighs	29	33	30	36
Knees	71	44	42	51
Ankles/Feet	29	24	27	31
1 or More	100	81	83	88

Although there are visibly pronounced differences in rates of pain across BMI groups, it is important to note that they are of much smaller magnitude than those across gender or hours per week worked. Ignoring the minutely-sized underweight category, the largest difference between rates in one area of the body barely exceeds ten percentage points for BMI, compared to differences of more than 25 percentage points across gender and hours per week.

A Unified Model for Musculoskeletal Pain

In order to look at both the relative and absolute statistical significance of the above variables in explaining rates of musculoskeletal pain in bus drivers, logistic regression models were created for each area of the body. The dependent variable is a 0/1 value indicating whether or not pain occurred in that area of the body, with 1 representing some level of pain and 0 representing no pain. The independent variables—age, gender, seniority, hours per week worked, and the BMI of respondents—have been considered in previous research as potentially influencing rates of musculoskeletal pain, or were expected to influence the dependent variable in these models.

The results are displayed in Tables 7 and 8, which correspond to rates of pain over the last 12 months and over the last 7 days, respectively. Each row represents the result of the logistic regression model for the specified area of the body.

Table 8. Logistic Regression Models for Each Body Area, Last 12 Months

	Age	Gender	Seniority	Hours/ Week	BMI	Nag. R^2	Model % Accuracy	Significant Model?
Neck	-	**+****	+	+	+	.048	59.5	Y
Shoulders	-	**+****	+	**+****	+	.062	58.4	Y
Elbows	-	**+****	+	+	+	.033	84.4	Y
Wrists/Hands	+	**+****	+	**+****	+	.073	70.2	Y
Upper Back	**-****	**+****	+	**+***	+	.064	71.2	Y
Lower Back	**-****	**+****	+	**+****	**+***	.068	63.5	Y
Hips/Thighs	+	**+****	+	**+***	+	.072	68.8	Y
Knees	-	**+****	+	**+***	**+***	.047	58.2	Y
Ankles/Feet	-	**+****	+	+	**+***	.031	72.4	Y
1 or More	-	**+****	+	**+****	**+***	.080	84.8	Y

+ indicates a positive correlation.
– indicates a negative correlation.
* indicates significance at p < .05 level.
** indicates significance at p < .01 level.
Bold indicates significance at p < .05 or p < .01 level.

Table 9. Logistic Regression Models for Each Body Area, Last 7 Days

	Age	Gender	Seniority	Hours/ Week	BMI	Nag. R^2	Model % Accuracy	Significant Model?
Neck	-	**+****	+	+	+	.032	77.2	Y
Shoulders	-	**+****	+	**+****	+	.064	73.7	Y
Elbows	+	**+****	+	+	+	.041	93.1	Y
Wrists/Hands	+	**+****	+	+	-	.054	86.3	Y
Upper Back	**-***	**+****	+	**+***	+	.034	85.8	Y
Lower Back	-	**+****	-	**+***	**+***	.054	72.0	Y
Hips/Thighs	+	**+****	+	**+****	-	.060	82.7	Y
Knees	+	**+****	-	**+***	**+****	.047	77.0	Y
Ankles/Feet	+	**+****	+	+	+	.054	85.6	Y
1 or More	+	**+****	-	**+***	**+****	.095	60.8	Y

+ indicates a positive correlation.
– indicates a negative correlation.
* indicates significance at p < .05 level.
** indicates significance at p < .01 level.
Bold indicates significance at p < .05 or p < .01 level.

Of all of the variables so far examined, differences in gender remained the most significant source of variation in rates of musculoskeletal discomfort among respondents. Other consistently significant explanatory variables in both models were the number of hours per week worked and, to a lesser extent, BMI. These observations follow intuitions gained from looking at each of these variables individually.

Though there are some statistically significant correlations, it is important to note the low pseudo-R squared values on all models. Not one of these models explains more than 10% of the variation in rates of musculoskeletal discomfort, and the model accuracies are low when the real frequencies are not below 15% or above 85%. In essence, the model does not explain a significant portion of the prevalence of musculoskeletal discomfort, and further, many outside factors that do affect these rates are not accounted for in these models.

RATES OF WORK PREVENTION AND MEDICAL VISITS/WORKER'S COMPENSATION

Table 10 shows the rate of respondents asserting that pain prevented them from doing their normal work, rates of pain-related doctor visits, and rates of workers' compensation claims as a percentage of rates of pain in the last 12 months for each area of the body.

Table 10. Rates of Work Prevention, Medical Visits, and Worker's Compensation for Those with Pain in Past 12 Months

	(%) of respondents with pain in the last 12 months who:		
	Were Prevented from Doing Normal Work	Visited Medical Professional	Applied for Worker's Compensation
Neck	31	46	8
Shoulders	31	42	11
Elbows	28	34	11
Wrists/Hands	31	33	11
Upper Back	35	48	11
Lower Back	42	45	10
Hips/Thighs	35	37	8
Knees	35	35	7
Ankles/Feet	34	40	9
1 or More	51	60	19

In general, for each area of the body, around 30–40% of those who had pain in the last 12 months were prevented from doing their normal work. Around 35–45% of this population visited a doctor or other medical professional to seek help for the pain in that area of the body, and around 10% applied for worker's compensation for pain in that area of the body. For respondents with one or more areas of pain, 51% had at least one of those areas prevent them from doing their normal work; 60% sought medical help, and 19% applied for worker's compensation for at least one of those areas.

The large gap in the percentage of respondents reporting that the pain prevented them

from doing their normal work and the rate of worker's compensation claims is a highly visible outcome. For all areas of the body, the gap is between around 20 to 30 percentage points. An even larger gap in rates of doctor's visits and worker's compensation claims exists, and although rates of doctor's visits are slightly more variable, they remain higher than rates of work prevention for each area of the body.

Differences across Gender

Table 11 outlines gendered differences in rates of work prevention, doctor visits, and worker's compensation for those with musculoskeletal pain in the past 12 months. Women with one area of pain or more in the last 12 months were prevented from doing their normal work more than men (11 percentage points), visited medical professionals more than men (17 percentage points), and applied for worker's compensation at nearly double the percentage that men with discomfort over the past year did.

Table 11. Gendered Differences in Work Prevention, Medical Visits, and Worker's Compensation

	(%) of respondents with pain in the last 12 months who:		
	Were Prevented from Doing Normal Work	Visited Medical Professional	Applied for Worker's Compensation
Male	48	56	15
Female	59	73	31

Differences across Hours per Week Worked

Table 12 shows differences in rates of work prevention, doctor visits, and worker's compensation for those with musculoskeletal pain in the past 12 months. Compared to differences across gender, differences here are of similar magnitude, although they are smaller. Full-time workers were prevented from doing their normal work 17 percentage points more than part-time workers, visited medical professionals 10 percentage points more, and applied for worker's compensation 7 percentage points more.

Table 12. Part-Time/Full-Time Differences in Work Prevention, Medical Visits, and Worker's Compensation

	(%) of respondents with pain in the last 12 months who:		
	Were Prevented from Doing Normal Work	Visited Medical Professional	Applied for Worker's Compensation
Part-Time	38	53	14
Full-Time	55	63	21

V. DISCUSSION

The following section discusses and analyzes the above results, comparing their relative significance and positioning them within existing literature and findings from similar surveys. It first looks at results related to rates of musculoskeletal discomfort, summarizing the large disparities in rates across gender and hours per week worked, and showing that the frequency of musculoskeletal discomfort is well above that of the general population. It then analyzes results related to work prevention, medical visits, and worker's compensation, also showing large disparities across gender. It also comments on the large gap between frequencies of the three variables, noting that the difference between rates of work prevention and worker's compensation claims underlines a large yet unrealized cost to King County Metro.

LARGE DISPARITIES IN RATES OF MUSCULOSKELETAL DISCOMFORT

The rates of musculoskeletal discomfort found in this study, especially in the areas with high prevalence, such as the lower back and knees, closely align with existing literature regarding such issues among occupational drivers. Specifically, the present findings mirror those of Szeto and Lam, who found similarly high rates of musculoskeletal issues in the lower back, shoulders, and neck areas of a smaller sample of Hong Kong bus drivers.[35]

Figures 3 and 4 show the rates of musculoskeletal discomfort of drivers in this survey as compared to rates of pain for the general population. Figure 3 regards rates of musculoskeletal pain in the last 12 months for selected body areas, which provides a direct comparison to results from this survey. The data in Figure 4, while more recent, regard rates of pain over the last 3 months. These data come from national surveys conducted by the CDC.

Both sets of data support the statement that bus drivers see considerably higher rates of musculoskeletal pain than the general population. The direct comparison between rates of pain over the last 12 months results in differences of more than 30 percentage points across all categories (Figure 3). Comparisons to more recent data show smaller gaps in rates of pain, but it is important to note that the more recent data consider rates of pain over 3 months and not 12 (Figure 4). Notably, rates of lower back pain in the last 7 days in this study were only 6 percentage points lower than those in the last 3 months in the general population. These consistently large gaps in rates of pain mirror the findings of previous studies by Yasobant et al., Magnusson et al., and Alperovitch-Najenson et al.[36]

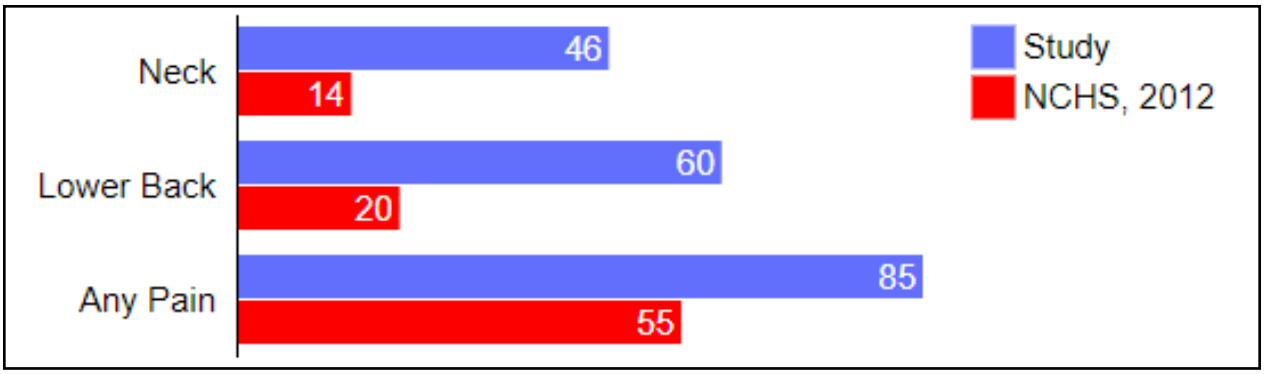


Figure 3. Rates of Musculoskeletal Pain (Last 12 Months), Selected Areas, Compared to General Population (2012)

Tainya C. Clarke, Richard L. Nahin, Patricia M. Barnes, and Barbara J. Stussman. "Use of Complementary Health Approaches for Musculoskeletal Pain Disorders Among Adults: United States, 2012." National Health Statistics Reports (October 2016).

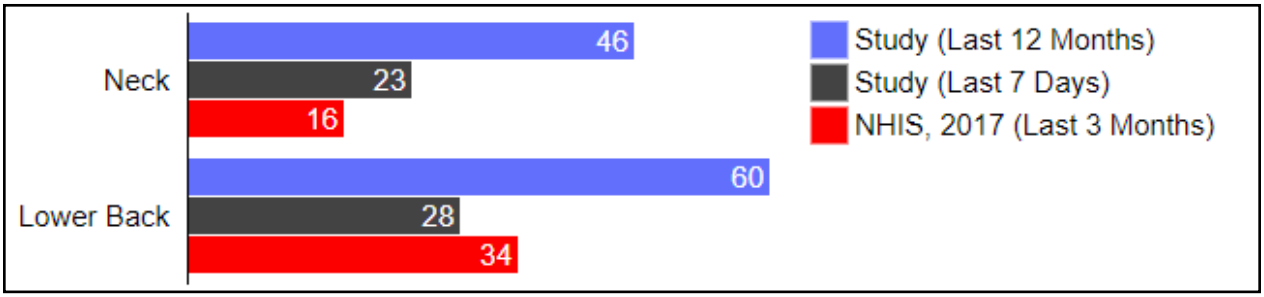


Figure 4. Rates of Musculoskeletal Pain, Selected Areas, Compared to General Population (2017)

2017 National Health Interview Survey (NHIS) Sample Adult Public Use File. ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2017/samadult_freq.pdf. September 2018.

One of the most notable findings of this survey is the difference in rates of pain across men and women (Table 4). In many areas of the body, differences were as large as 20–25 percentage points. This finding was confirmed in the logistic regression models, which showed that the differences in rates were statistically significant at the .01 level for all areas of the body (Tables 8 and 9). As the study does not ask about variables potentially linked to this outcome, it is not possible to determine the reasons for such a large gap in rates of discomfort between men and women. Although few studies on musculoskeletal health in bus drivers have reached similarly strong conclusions in this regard, these findings do mirror those of Wei et al., who, in a study with a similar gender balance in the population of respondents, found higher rates of musculoskeletal problems among female transit drivers.[37]

Differences in rates of pain across hours per week worked were also consistently noticeable, though to a lesser degree than differences across gender. The gap between full-time and part-time workers was consistently smaller and less statistically significant than that between men and women, and the logistic regression model included hours per week as a statistically significant variable less often and at weaker confidence levels. Although the effect on musculoskeletal pain of hours per week worked is clear, there was not a consistent 'cut-off' point in hours per week past which rates of pain were seen to

significantly increase. One surprising finding was that many areas of the body saw pain rates decrease once workers passed the 60 hours per week mark (Table 5). A possible explanation for this finding is that drivers experiencing discomfort would have less incentive to sign up for additional overtime shifts.

One of the more surprising results is the lack of strong patterns of injury rates across different seniorities. Although the possible effects of grouping seniorities into 5-year segments might seem to confound results, looking at the results in one- or two-year segments returns a similarly random pattern. Most notably, those with seniority under one or two years still have high rates of musculoskeletal pain compared to the rest of the population (Figure 1). This finding could stem from the survey's failure to ask about previous employment, outside activities, or existing health conditions unrelated to driving. Unsurprisingly, seniority was never a significant variable in the logistic regression models (Tables 8 and 9).

However, as Alperovitch-Najenson et al. found in their survey of 384 bus operators in Tel Aviv, looking at injury rates across age does show a visible but tame healthy worker effect, wherein rates of pain decrease in older drivers, as those with injury or pain are forced to retire or find other employment earlier on.[38] Because the rates of pain were lower in the youngest groups, the U-shaped distribution of pain across the age variable meant that it was not significant in the logistic regression models, which did not account for quadratic relationships between variables (Figure 1, Tables 8 and 9).

The consistently positive and sometimes statistically significant relationship between pain and BMI somewhat follows previous findings of the effects of driver health on well-being and discomfort. However, as previously noted, the influence of BMI appears to be less significant than that of gender or hours worked. This is true when looking at raw percentages, and is substantiated in the logistic regression models (Tables 7–9). In order to assess the role of driver health in determining outcomes of musculoskeletal discomfort, it would be critical to collect more information from the respondents, such as physical activity, stress levels, and job demands, as previous studies have done.

The logistic regression models, while significant, explained very little of the variation in rates of musculoskeletal discomfort for all areas of the body (Tables 8 and 9). While a small portion of the variability in rates of discomfort can be explained by the differences in demographic variables among bus drivers, there are still many factors missing in this analysis. More importantly, the consistently high rates of discomfort across all strata of respondents indicate that, regardless of demographics, it is reasonable to expect high rates of musculoskeletal discomfort among all bus drivers, regardless of seniority, age, body mass index, or gender, and to expect that these rates will be well above those of the general population.

LARGE DIFFERENCES BETWEEN WORK PREVENTION AND MEDICAL VISITS/WORKER'S COMPENSATION CLAIMS

There were large gaps between rates of work prevention, medical visits, and worker's compensation. Because the severity of the pain is not asked about in the survey, these differences cannot be explained with data obtained in the survey. However, the high rate (60%) of those with any pain in the last 12 months visiting a medical professional demonstrates a considerable cost to the healthcare system (Table 10). Furthermore, the large difference (more than 40 percentage points) in between the rates of medical visits and worker's compensation claims for those experiencing discomfort shows a potentially huge and yet unrealized cost to King County Metro. Explaining the difference between these two is difficult, but many drivers, in personal conversations, seemed to imply that they did not consider worker's compensation as an option or were not aware of the program. One respondent even circled the worker's compensation question on the survey and wrote next to it, "Didn't know I could."

Differences in the rates of these variables across gender are similar in magnitude to the differences in rates of musculoskeletal pain. Women who had experienced musculoskeletal pain in the past 12 months were more likely than men to be prevented from doing their normal work (by more than 10 percentage points), to visit the doctor (by more than 15 percentage points), and to apply for worker's compensation (by more than 15 percentage points; see Table 11).

Differences in rates of these variables across part-time and full-time drivers are also similar to the differences in the rates of musculoskeletal pain between the two. Although there were similar gaps between part-time and full-time drivers in terms of work prevention, with full-time drivers more likely to be prevented from doing their work, the magnitude of the difference narrows noticeably when it comes to worker's compensation claims (Table 12). The additional burden of applying for worker's compensation with a full-time schedule could be a factor, but the survey does not provide the apparatus to substantiate such an intuition.

VI. CONCLUSIONS AND FURTHER RESEARCH

KEY FINDINGS

A vast majority of respondents reported having pain in at least one area of the body in the last 12 months (85%). For female respondents, rates were consistently more than 15 percentage points higher for all areas of the body in the last 12 months. Notably, 95% of female respondents reported having discomfort in at least one area of the body in the last 12 months, compared to 82% of men. A similarly visible but less pronounced difference was found between full-time and part-time workers. However, for many areas of the body, those working more than 60 hours per week reported lower rates of discomfort than those working 40–59 hours a week. This finding is suspected to be the case because full-time drivers with existing musculoskeletal pain would be less inclined to take on more overtime shifts compared to those without or with less pain. BMI had a visible but less significant positive correlation with rates of discomfort as well. While seniority was not found to have a significant relationship, looking at rates of discomfort across the age of drivers revealed a visible healthy worker effect, where due to early retirement because of repeated injury or discomfort, there is an inverted U-shaped pattern of injury rates across drivers' age.

The logistic regression models, while confirming the results above in terms of statistical significance, showed through consistently low pseudo-R squared and outcome prediction values that these work-related and sociodemographic variables still explain only a small proportion of the prevalence of musculoskeletal pain in bus drivers. Existing literature has pointed to many other explanations to bridge this gap, such as the buses themselves, job demands, stress, and other health indicators. More to the point, rates of musculoskeletal pain over the last 7 days in the survey were comparable to those of the general population over the last 3 months, according to 2017 data from the CDC. This gap becomes even larger when considering rates of pain over the last 12 months from the survey.

Lastly, the questions about rates of work prevention, medical visits, and worker's compensation revealed a large gap for those reporting pain in the last 12 months between rates of medical visits and worker's compensation claims. Of note was the large gap in the rates of all three of the above variables across men and women; women who had musculoskeletal pain in the 12 months before the survey were prevented from doing their normal work, visited medical professionals, and applied for worker's compensation 10 or 15 percentage points more than men did. Similarly, full-time workers with discomfort in the last 12 months were prevented from doing their normal work at much higher rates as well, but the gap lessened considerably for worker's compensation claims.

LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The design and scope of the survey does somewhat limit the findings herein. For example, the survey did not ask about factors that could have influenced musculoskeletal pain, nor did it ask respondents to try to identify the source of their pain. Future studies on the subject should ask about both job-related and outside potential influences on musculoskeletal disorders. Job-related factors less studied in the existing literature include the vehicles and routes drivers are normally assigned to and the types of shifts drivers work. Outside

factors like hobbies and previous employment should also be included. The gender imbalance of surveys in current literature and the relatively small research on gendered differences in rates of MSDs should be addressed, and investigations on the role of other sociodemographic factors, such as race or class, are equally lacking. As this survey did not address variables such as race or class, there is no discussion their influence herein, but they are potentially very important and must be discussed in future literature on musculoskeletal pain.

Another potentially important limitation is the fact that the survey does not differentiate between levels of pain, and does not ask users to identify the duration of the pain. It also does not ask about pre-existing conditions. Such information would be crucial in better understanding the gaps between rates of pain, work prevention, medical visits, and worker's compensation claims. More detailed, longitudinal studies could help better evaluate the potential burden on the healthcare system, transit agencies, and workers themselves.

In addition to the above recommendations, further research should aim to quantify the potential effects of improved bus workstation design and altered route types on bus drivers. Although existing research has measured the exposure of bus drivers to WBVs, the effects of this exposure have not been quantified and could be an important explanatory variable in an analysis similar to this one. Many smaller aspects of the workstation space, such as bus placement, seat height, seat and pedal adjustability, and viewing angles have gone unnoticed in most existing literature. Additionally, potential differences in rates of musculoskeletal discomfort based on which types of routes drivers operate should be investigated. Factors for such research could include the surface type of roads, route length, and the number and location of stops, among others.

POLICY IMPLICATIONS

Perhaps the most important policy recommendation from this study is the need for significant, high-level interventions at transit agencies to mitigate potential sources of musculoskeletal pain in bus drivers. The large gap between the number of workers who visited a medical professional for their pain and the number who applied for worker's compensation suggests the existence of a large, but yet unrealized, financial burden on King County Metro. Although claims related to back pain already represent 13% of total costs to the agency, the aforementioned gap suggests that the proportion could yet increase.[39]

Specific policy improvements at the agency level have the potential to better mitigate musculoskeletal discomfort in bus drivers. Changes in bus procurement, such as the provision of active-suspension seats for bus drivers, is one potential avenue. Increasing the participation of drivers in the process would help future rolling stock better address ergonomic concerns. Many drivers at King County Metro mentioned that even seemingly small details, such as the placement of buttons or other controls in the drivers' workstations, have important effects on well-being while driving, and subsequently, over the long-term. Another intervention recommended in previous literature is better training for bus drivers and more realistic recruitment processes. Although these have a less direct relationship with musculoskeletal health issues, they have the potential to help with stress and regressive coping tendencies, which have been linked to poor health in the long-term. Lastly, better

bus routes and road design have the potential to directly mitigate both some of the stress and musculoskeletal health issues drivers face on the job. As mentioned above, however, further research must aim to quantify the effects of these interventions and investigate other avenues to improving drivers' musculoskeletal health.

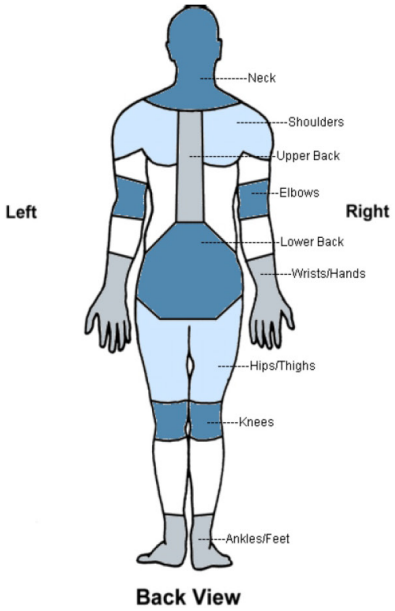
APPENDIX A: SURVEY QUESTIONNAIRE

ATU Anonymous Survey

Musculoskeletal Discomfort

Years of Seniority_____
Hours per Week _____
Age_____ Gender_____
Height_____ Weight_____

Part Time ☐ or Full Time ☐
Female ☐ Male ☐



Back View

To be answered by everyone	To be answered by those who have had trouble							
Have you at any time during **the last 12 months** had trouble (ache, pain, discomfort, numbness) in:	Have you at any time **during the last 12 months been prevented from doing your normal work** (at home or away from home) because of the trouble?		Have you had trouble at any time **during the last 7 days**?		Have you gone to a doctor or other healthcare provider for this trouble?		Have you applied for **worker's compensation** for this trouble?	
Neck ☐ No ☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Shoulders ☐ No ☐ Yes, right shoulder ☐ Yes, left shoulder	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Elbows ☐ No ☐ Yes, right elbow ☐ Yes, left elbow	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Wrists/Hands ☐ No ☐ Yes, right wrist/hand ☐ Yes, left wrist/hand	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Upper Back ☐ No ☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Lower Back (small of back) ☐ No ☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Hips/Thighs ☐ No ☐ Yes, right hip/thigh ☐ Yes, left hip/thigh	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Knees ☐ No ☐ Yes, right knee ☐ Yes, left knee	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Ankles/Feet ☐ No ☐ Yes, right ankle/foot ☐ Yes, left ankle/foot	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes

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ABBREVIATIONS AND ACRONYMS

BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
MSD	Musculoskeletal Disorder
TCRP	Transit Cooperative Research Program
WBV	Whole-Body Vibration

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