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Ergonomic Risk, Occupational Fatigue and Musculoskeletal Disorders among Drivers of a Public Transport Company in Quito, Ecuador

¹Tatiana Lisseth Merchán Rosero, ²Jessica Valeria Medrano Aulestia, ³Klever Sango Calo

¹Universidad Técnica del Norte, Ecuador

tmerchanr@utn.edu.ec

ORCID: <https://orcid.org/0009-0008-9016-4661> (Corresponding author)

²Universidad Técnica del Norte, Ecuador

jessvalmedrano@hotmail.com

ORCID: <https://orcid.org/0009-0000-3940-262X>

³Universidad Técnica del Norte, Ecuador

kvsango@utn.edu.ec

ORCID: <https://orcid.org/0009-0003-9231-7530>

ABSTRACT: Background. Urban public-transport drivers are simultaneously exposed to static postural load, whole-body vibration and extended shifts, factors associated with musculoskeletal disorders (MSDs) and occupational fatigue. In Quito, Ecuador, the topographic conditions and long working hours add specific demands that have been scarcely studied.

Objective. To determine the prevalence of musculoskeletal disorders (MSDs) and their association with ergonomic risk factors and occupational fatigue among drivers of a public transport company in Quito, Ecuador.

Methods. Analytical cross-sectional study of the entire active driver population (census, $n = 30$) of a cooperative operating an urban route in southern Quito. A sociodemographic/occupational form, the Nordic Musculoskeletal Questionnaire, the REBA and RULA postural assessment methods and the Yoshitake Fatigue Symptoms Questionnaire were applied. Prevalences were estimated with Wilson 95% confidence intervals, correlations with Spearman's rho and group comparisons with the Mann–Whitney U test. A predefined family of 80 exploratory tests was adjusted by the Benjamini–Hochberg procedure ($FDR < 0.05$).

Results. All drivers (100%; 95% CI 88.6–100) reported symptoms in at least one body region in the previous 12 months and 70.0% (52.1–83.3) in the previous 7 days. The most affected regions were upper/lower back and elbow/forearm (80.0% each), shoulder (76.7%) and neck (73.3%). RULA placed all 30 drivers at action level 3; REBA classified 80.0% at medium risk and 20.0% at high risk. The mean Yoshitake score was 13.00 ± 5.88 . No significant association was found between RULA/REBA scores and fatigue, nor between total fatigue and the number of symptomatic regions. After adjustment, age and driving experience were positively associated with the number of symptomatic regions, and perceived vibration intensity was positively associated with total fatigue ($q = 0.526$; $q = 0.033$).

Conclusions. The drivers assessed show a very high musculoskeletal burden and postural exposure requiring intervention, together with subjective fatigue symptoms. Age, driving

experience and perceived vibration emerged as key associated variables. The results provide a baseline for surveillance of health in this occupational group

1. INTRODUCTION

Public transport worldwide constitutes an occupation with high exposure to ergonomic and psychosocial risk factors, in which the levels of fatigue to which drivers are exposed can be directly observed. This is due to several causes, such as rotating shifts, city traffic and noise, prolonged sedentarism and inadequate postures maintained during long working hours that include vibrations and repetitive movements, generating greater stress and occupational fatigue in drivers, as well as a possible deficit in reaction capacity in the event of a crash (Serrano-Fernández et al., 2019). Bus drivers rank among the three occupations with the highest rates of musculoskeletal disorders (MSDs) in occupational surveillance registries, and the international literature has documented prevalences of musculoskeletal pain in professional drivers ranging from 43% to 93%, with the lumbar region as the most frequent location (Joseph et al., 2020).

Recent systematic reviews confirm the magnitude of the problem. A meta-analysis of 22 studies estimated an overall MSD prevalence in bus drivers of 73.9% (95% CI: 64.4–83.4), with the lumbar region predominating (Makki et al., 2025). Pickard et al. (2022), synthesizing 25 studies published between 2006 and 2021, identified prolonged sitting hours, years in the profession, vehicle ergonomics and vibration as recurrent risk factors. Joseph et al. (2023), applying Bradford Hill causality criteria to 54 studies, reported strong evidence for the causal relationship between awkward postures, whole-body vibration, work demands and MSDs in this group, although the evidence regarding the role of age, driving years and body mass index was inconclusive. In primary studies using the Nordic Questionnaire, annual prevalences in neck and back reach 82% and 81% in Thai bus drivers (Kasemsan et al., 2021), 68% and 57% in Portuguese drivers (Silva et al., 2025) and 66% overall in drivers in southern India (Thangamuthu et al., 2025).

The mechanisms involved are multiple and reinforce each other. Prolonged occupational sitting is associated with higher odds of low back pain (OR = 1.47) and neck/shoulder pain (OR = 1.73) in meta-analyses of cross-sectional studies (Dzakpasu et al., 2021). Occupational exposure to whole-body vibration is associated with an approximately twofold higher prevalence of low back pain (pooled OR = 2.17; 95% CI: 1.61–2.91) and sciatica (OR = 1.92; 95% CI: 1.38–2.67) according to a meta-analysis of 20 studies (Burström et al., 2015), and bus-driver-specific reviews identify it as a consistent risk factor, especially when combined with inadequate postures that amplify its transmission (Mendes et al., 2021). Added to this is the organizational dimension: urban transit drivers frequently work irregular shifts and extended hours that exceed their physiological recovery capacity (Kim et al., 2018), report poor sleep quality in proportions close to two-thirds (Chaiard et al., 2019) and experience drowsiness at the wheel on a regular basis (Anund et al., 2016; Lee et al., 2017). Recent evidence from 1,792 bus drivers shows that poor sleep quality multiplies the risk of multi-site MSDs by 3.7 and that each additional hour of nighttime sleep reduces that risk by 36%, mediating nearly half the effect of occupational stress on MSDs (Wang et al., 2025).

In Ecuador, the Ministry of Public Health, in its publication “Panorama Nacional de Salud de los Trabajadores – Encuesta de Condiciones de Trabajo y Salud 2021–2022” [National Workers’ Health Panorama – Working Conditions and Health Survey 2021–2022], notes that driving constitutes an occupation with significant exposure to factors that may promote the onset of MSDs, due to conditions such as irregular schedules, route changes, short meal breaks and reduced physical activity (Ministerio de Salud Pública del Ecuador, 2022). In the Andean context, studies on intercity bus drivers have documented musculoskeletal alterations attributable to driving posture and work organization (Moreno Vega, 2020), in Colombian urban transport drivers it has been observed that overweight and obesity, common in this group, are associated with lower physical fitness and higher frequency of musculoskeletal complaints (Mendinueta-Martínez et al., 2019), and in 1,607 workers in the metropolitan transit system of Belo Horizonte self-assessed job precariousness was associated with worse health, including musculoskeletal pain in 43% of cases (Simões et al., 2019). A Spanish-language systematic review of working conditions and health of public transport drivers in Latin America concluded that this group exhibits unfavorable working conditions, with simultaneous presence of physical and psychological risks, overweight, musculoskeletal diseases and anxiety-depressive symptoms (Arias-Meléndez et al., 2022).

The limited information and research on the joint relationship between ergonomic risk, occupational fatigue and musculoskeletal disorders in public transport drivers in the city of Quito is especially relevant considering the high vehicular load in Ecuador’s capital, which is growing rapidly. Added to this are the topographic and climatic conditions of a city situated

at more than 2,800 m above sea level, with steep slopes, high passenger demand and vehicular congestion resulting from the lack of roads connecting the city from north to south, conditions that the Metropolitan District's own Sustainable Mobility Master Plan recognizes as determinants of public transport operations (Municipio del Distrito Metropolitano de Quito, 2024). These characteristics may modify the physical demands to which the driver is subjected and, therefore, constitute elements that should be considered when analyzing their ergonomic exposure.

In this context, the general objective of this research was to determine the prevalence of musculoskeletal disorders (MSDs) and their association with ergonomic risk factors and occupational fatigue among drivers of a public transport company in Quito, Ecuador. The specific objectives were: (1) to estimate the prevalence of musculoskeletal symptoms by body region (neck, shoulders, upper back, lower back, hips, knees, ankles, elbows, wrists) in the company's drivers; (2) to assess the ergonomic risk level associated with the driving posture through direct observation; (3) to measure the level of occupational fatigue perceived by the drivers: general, physical and mental fatigue; and (4) to explore the association of sociodemographic and occupational factors with musculoskeletal symptoms, ergonomic risk and occupational fatigue. The hypothesis was that drivers with higher ergonomic risk levels during driving would present a higher prevalence of musculoskeletal disorders and higher levels of occupational fatigue.

2. MATERIALS AND METHODS

2.1. Design and context

An analytical cross-sectional study with a quantitative approach was conducted, with the unit of analysis being the assessment of each driver, reported in accordance with the STROBE statement for cross-sectional studies. Data collection was carried out throughout the month of September 2026. For the study, the Santa Isabel route (El Beaterio area, in southern Quito) to the Seminario Mayor (in the north-center, Universidad Central area) was selected as the assessment scenario, an autonomous route of the transport cooperative. The selection of a common route allowed standardization of driver observation conditions, reducing the variability that could arise from conducting evaluations on routes with different operational characteristics; the segment from Quicentro del Sur to the Chimbacalle Station was used for the study, as it constitutes a partially linear route.

2.2. Participants

The study population consisted of the 30 active drivers of a public transport cooperative in Quito. A census of this population was conducted: all drivers were invited to participate and all 30 agreed and signed the informed consent form, so there was no sampling or exclusion due to refusal. This approach ensured a participation rate of 100%, which strengthens internal validity and avoids selection bias in this specific group.

The inclusion criteria were: active drivers with at least six months of tenure, over 18 years of age and voluntary acceptance through informed consent. Drivers with temporary medical leave at the time of data collection were excluded. No driver met the exclusion criterion, so the study population coincided with the eligible population.

2.3. Instruments and variables

Sociodemographic and occupational form. The purpose of the form was to collect basic and occupational information from the personnel that would allow characterizing the study population and identifying the variables, individual or occupational, that could be related to the presence of musculoskeletal disorders and occupational fatigue (Joseph et al., 2023). The following were recorded: age, sex, marital status, education level, self-reported weight and height (from which the body mass index, BMI, was calculated), physical activity outside work and its frequency, nighttime sleep hours, perception of rest sufficiency, medication use, tobacco and alcohol consumption, tenure at the company and as a professional driver, shift type, work hours and effective driving hours per shift, days worked per week, maximum continuous driving time, duration and number of daily breaks, and history of diagnosed musculoskeletal disease.

Perceived vibration. Considering that professional driving may involve exposure to whole-body vibration, the study assessed only subjective vibration perception, which constitutes an exploratory variable and not an objective measurement in accordance with ISO 2631, through questions incorporated into the sociodemographic and occupational form regarding vibration perception during driving, its frequency (never, sometimes, frequently, almost always), its intensity on a five-category scale (very low, low, moderate, high, very high) and the conditions under which the driver considered it to be most intense (Pickard et al., 2022). For analysis, frequency was coded from 0 (never) to 3 (almost always) and perceived intensity ordinally from 1 (low or very

low) to 4 (very high), assigning a value of 0 to drivers who reported not perceiving vibration. The 'very low' and 'low' categories were grouped due to their low frequency (1 and 2 drivers, respectively); a sensitivity analysis with the five-level coding produced virtually identical coefficients (e.g., with total fatigue $\rho = 0.526$ versus $\rho = 0.532$), so the grouping did not modify the conclusions (Table S3 of the supplementary material). This information was used as a complementary variable to characterize the participants' working conditions, given that no specific instrumentation was available to measure acceleration.

Kuorinka Nordic Questionnaire for musculoskeletal disorder assessment. The Standardized Nordic Questionnaire is a validated instrument for identifying the presence of musculoskeletal disorder symptoms in different body regions (Kuorinka et al., 1987). The general version adapted and validated in Spanish was used (Mateos-González et al., 2024), considering the previous 12 months and the previous 7 days as reference periods, which allowed identifying musculoskeletal symptoms in both a prolonged and a recent period. In the version applied, the dorsal and lumbar regions were collected as a single region ('dorsal or lumbar'), so eight body regions were assessed: neck, shoulder, upper/lower back, elbow/forearm, wrist/hand, hips/thighs, knees and ankles/feet. The symptoms recorded correspond to self-reported complaints and not to a clinical diagnosis of MSDs. A driver was considered to have musculoskeletal symptoms if they reported pain or discomfort in at least one of the body regions assessed during the reference period; additionally, the number of symptomatic regions per driver was calculated as a multi-site burden indicator. Responses were dichotomous (Yes = 1; No = 0) for each body region. The questionnaire was administered individually to drivers who agreed to participate and signed the informed consent form; before administration, filling instructions were explained and only questions related to comprehension were addressed, avoiding influencing the responses. The information was recorded using a code assigned to each driver to preserve confidentiality.

Postural assessment using the REBA and RULA methods. For postural assessment, the Rapid Entire Body Assessment (REBA) was used as the primary method and the Rapid Upper Limb Assessment (RULA) as a complementary method, both applied through systematic observation of audiovisual recordings obtained during regular driving. REBA characterized the postures adopted during driving considering neck, trunk, upper and lower limbs, as well as the other factors contemplated by the method (Hignett & McAtamney, 2000); its use as the primary method was justified by allowing a global body assessment and determining the postural risk level. Complementarily, RULA, which focuses directly on sustained exposure of neck, shoulders, arms, forearms and wrists, was used for exposure at the steering wheel and cabin controls (door controls, cameras, passenger service), allowing greater emphasis on upper body segments (McAtamney & Corlett, 1993).

The assessment was conducted by taking audiovisual recordings in 10-minute periods per driver, obtained during regular driving and under normal working conditions, without interfering with task safety. The representative segment was defined as one in which the driver remained performing their regular driving activity with the actions inherent to the task, such as steering wheel and control manipulation, without extraordinary interruptions unrelated to the activity. From the recording, two postures per driver were selected: P1, corresponding to the regular or stable driving posture, and P2, corresponding to the posture of greatest postural demand observed in the segment, defined as the one with the greatest upper limb reach and most marked postural modification relative to stable driving (for example, when operating door or camera controls). In each posture, neck, trunk and legs were scored once, while the upper limb (arm, forearm and wrist) was scored separately for the right and left side, according to the scoring criteria of each method; thus, four RULA and four REBA scores were obtained per driver (120 per method), recorded in a matrix with traceability to the driver code and corresponding audiovisual recording. To complement the assessment of body segments that were not clearly visible in the main audiovisual recording, especially the lower extremities located under the steering wheel, direct in situ observations were made during driving and frames obtained from other angles with better visibility were used. This complementary information allowed verifying the posture adopted by the driver and assigning the corresponding scores according to the criteria established by the RULA and REBA methods. For descriptive and association analyses, the maximum score among the four assessments was used. Scores were classified according to RULA action levels (1–2: acceptable; 3–4: investigate; 5–6: investigate and change soon; 7: investigate and change immediately) and REBA risk levels (1: negligible; 2–3: low; 4–7: medium; 8–10: high; ≥ 11 : very high).

The assessment was performed by a single evaluator previously trained in the application of the REBA and RULA methods, who conducted both the review of the audiovisual recordings and the score assignment. To control intra-observer agreement and reduce the variability associated with observational assessment, a sample of the recordings was reassessed by the same researcher at a different time, without consulting the scores obtained in the first assessment.

Yoshitake Questionnaire for fatigue assessment. As a specific instrument for assessing occupational fatigue, the Yoshitake Subjective Fatigue Symptoms Questionnaire was used in its original version in the Spanish language, which allows identifying subjective manifestations of fatigue associated with work activities through dichotomous responses (Yes/No) and organizes symptoms into three dimensions: general fatigue symptoms (drowsiness, heaviness, yawning; items 1–10), difficulty concentrating (items 11–20) and physical projection of deterioration or bodily discomfort (pain, stiffness, leg tiredness; items 21–30) (Yoshitake, 1978).

The questionnaire was self-administered. Prior to its application, participants received a standardized explanation of the filling procedure and the meaning of the instructions. During its application, support was provided only when necessary to clarify the comprehension of a question, taking care not to guide or influence the participants' responses.

The instrument was administered to all 30 drivers under standardized conditions, at the end of the workday or established driving period, with the purpose of assessing the presence of fatigue symptoms in situ and analyzing their relationship with working conditions, ergonomic risk and musculoskeletal disorders. For quantifying results, each affirmative response received 1 point and each negative 0 points, so the score per dimension ranges from 0 to 10 and the total score from 0 to 30, with higher values indicating a greater presence of subjective fatigue symptoms. No diagnostic cutoff point was applied, given that no validated threshold is available for this version of the instrument in the study population; the internal consistency of the 30 items was estimated using Cronbach's α coefficient.

2.4. Ethical considerations

The research was conducted in accordance with the ethical principles of voluntary participation, confidentiality, privacy and protection of participants' identity. The research topic was approved by the Honorable Board of Directors of the Graduate School of the Universidad Técnica del Norte through Resolution UTN-FP-CD-2026-007, dated January 9, 2026, within the framework of the Master's Program in Occupational Hygiene and Health, and the study received written authorization from the transport cooperative. Prior to data collection, each driver was informed about the study's objectives and procedures and provided written informed consent. Data obtained through questionnaires, in situ assessments and audiovisual recordings were used exclusively for academic and research purposes; each participant was assigned a code (C01–C30), avoiding the recording of personal information. Videos were treated confidentially, faces were obscured or blurred in all images used for analysis and access was restricted to the principal investigator. Results are presented in aggregate and anonymous form and were not used to evaluate job performance, apply sanctions or generate disadvantages for participants, who could withdraw from the study at any time without consequences.

2.5. Statistical analysis

Qualitative variables were summarized using absolute frequencies and percentages, while quantitative variables were described using mean and standard deviation (SD) or median and interquartile range (IQR), depending on their distribution. The normality of quantitative variables was assessed using the Shapiro–Wilk test, complemented with graphical inspection. The 95% confidence intervals (95% CI) for means were obtained using the t distribution and those for medians using the percentile bootstrap with 20,000 resamples. The prevalences of musculoskeletal symptoms obtained with the Nordic Questionnaire were expressed as absolute frequencies and percentages accompanied by 95% CI calculated by the Wilson method, considering the study population size ($n = 30$) and the presence of proportions close to the limits of 0 and 1; this method exhibits more adequate behavior than the Wald approximation in small samples and with extreme proportions (Newcombe, 1998).

For the bivariate analysis, the association between categorical variables was assessed using Pearson's χ^2 test when its assumptions were met and, in the presence of small expected frequencies, using Fisher's exact test. The relationship between ordinal or quantitative variables that did not meet normality assumptions was analyzed with Spearman's rank correlation coefficient (ρ), and the comparison of quantitative variables between two independent groups with the Mann–Whitney U test. Three sets of associations were examined, defined before data analysis: (i) maximum RULA and REBA scores versus fatigue scores, total and by dimension (8 tests); (ii) total fatigue score versus the number of symptomatic regions at 12 months and 7 days, and versus the presence of symptoms in each region and period (2 correlations and 13 computable U comparisons); and (iii) 13 quantitative or ordinal sociodemographic and occupational factors (age, BMI, sleep hours, company tenure, driving experience, work hours and driving hours per shift, days worked per week, continuous driving time, break duration and number, and perceived vibration intensity and frequency) and 3 dichotomous factors (physical activity, perceived rest sufficiency and vibration perception) versus

five outcomes (number of symptomatic regions at 12 months and 7 days, maximum RULA, maximum REBA and total fatigue). Set (iii) comprised 80 tests (65 Spearman correlations and 15 U tests) and, given its exploratory nature, its p-values were jointly adjusted using the Benjamini–Hochberg procedure (1995), which controls the false discovery rate (FDR) and supplements the original p-value with an adjusted value, commonly denoted q; $q < 0.05$ was considered significant. Sets (i) and (ii) correspond to the stated hypothesis and, given their reduced number of comparisons, were interpreted with a significance level of $p < 0.05$ two-sided without multiplicity adjustment. When appropriate, association measures were accompanied by their 95% CI. Analyses were performed in Python 3.12 (pandas, SciPy, statsmodels); the code and anonymized data are provided as supplementary material as indicated in the Declarations section.

3. RESULTS

3.1. Sociodemographic and occupational characteristics

The population consisted of 30 drivers, all male, with a mean age of 44.43 ± 8.68 years (95% CI: 41.19–47.67) and a mean BMI of 32.58 ± 6.59 kg/m² (95% CI: 30.12–35.04), a value that places the group, on average, in the obesity range. Of the participants, 56.7% had secondary education and 43.3% were married. Although 80.0% reported engaging in physical activity outside work, 86.7% considered their rest or sleep time insufficient, with a median of 6 hours of sleep per night (IQR: 5–6).

Regarding occupational characteristics, the median driving experience was 11.5 years (IQR: 7.25–15.0), while the usual shift lasted 12 hours (IQR: 11–14) and effective driving time was 11 hours (IQR: 10–12). Participants predominantly worked six days per week and had a median of three hours of continuous driving before a break, the usual duration of which was 5 minutes. The mixed shift predominated in 76.7% of participants. Finally, 90.0% (95% CI: 74.4–96.5) reported perceiving vibrations transmitted from the vehicle to the body, mainly at frequencies of ‘almost always,’ ‘sometimes’ and ‘frequently,’ and half of the participants rated it as high or very high intensity (Table 1).

Table 1. Sociodemographic and occupational characteristics of the drivers (n = 30).

Variable	Category / statistic	Result	95% CI
Quantitative variables			
Age (years)	Mean $\pm$ SD	44.43 $\pm$ 8.68	41.19–47.67
BMI (kg/m ²)	Mean $\pm$ SD	32.58 $\pm$ 6.59	30.12–35.04
Sleep hours/night	Median (IQR)	6.00 (5.00–6.00)	5.00–6.00
Company tenure (years)	Median (IQR)	8.00 (4.25–11.50)	5.00–10.00
Driving experience (years)	Median (IQR)	11.50 (7.25–15.00)	9.00–15.00
Work hours per shift	Median (IQR)	12.00 (11.00–14.00)	11.00–12.00
Effective driving hours/shift	Median (IQR)	11.00 (10.00–12.00)	10.00–11.50
Days worked/week	Median (IQR)	6.00 (6.00–6.00)	6.00–6.00
Continuous driving before break (h)	Median (IQR)	3.00 (3.00–4.00)	3.00–4.00
Usual break duration (min)	Median (IQR)	5.00 (3.25–5.00)	4.00–5.00
Number of breaks/day	Median (IQR)	5.00 (4.00–5.00)	4.00–5.00
Qualitative variables			
		n (%)	
Sex	Male	30 (100.0)	88.6–100.0
Marital status	Married	13 (43.3)	27.4–60.8
	Divorced	7 (23.3)	11.8–40.9

Variable	Category / statistic	Result	95% CI
	Single	5 (16.7)	7.3–33.6
	Cohabiting	4 (13.3)	5.3–29.7
	Widowed	1 (3.3)	0.6–16.7
Education level	Secondary	17 (56.7)	39.2–72.6
	Primary	8 (26.7)	14.2–44.4
	University	3 (10.0)	3.5–25.6
	Technical / technological	2 (6.7)	1.8–21.3
Physical activity outside work	Yes	24 (80.0)	62.7–90.5
Rest/sleep considered sufficient	No	26 (86.7)	70.3–94.7
Usual shift type	Mixed	23 (76.7)	59.1–88.2
	Rotating	5 (16.7)	7.3–33.6
	Morning / afternoon	2 (6.7)	1.8–21.3
Perceives vibrations transmitted by the vehicle	Yes	27 (90.0)	74.4–96.5
Perceived vibration frequency	Almost always	10 (33.3)	19.2–51.2
	Sometimes	9 (30.0)	16.7–47.9
	Frequently	8 (26.7)	14.2–44.4
	Never	3 (10.0)	3.5–25.6
Perceived vibration intensity	Moderate	9 (30.0)	16.7–47.9
	High	9 (30.0)	16.7–47.9
	Very high	6 (20.0)	9.5–37.3
	Low / very low	3 (10.0)	3.5–25.6
	Not applicable (does not perceive)	3 (10.0)	3.5–25.6

Note. SD = standard deviation; IQR = interquartile range. Normality was assessed with the Shapiro–Wilk test. Variables with a distribution compatible with normality are presented as mean $\pm$ SD and 95% CI of the mean (*t*); the remaining variables are presented as median (IQR) and 95% CI of the median via percentile bootstrap (20,000 resamples). 95% CI for proportions: Wilson method.

3.2. Prevalence of musculoskeletal symptoms

The Nordic Questionnaire assessment revealed a high frequency of musculoskeletal symptoms in the study population. During the previous 12 months, all 30 drivers (100.0%; 95% CI: 88.6–100.0) reported complaints in at least one body region. The highest prevalences corresponded to the upper/lower back and elbow/forearm regions, both at 80.0% (95% CI: 62.7–90.5), followed by shoulder at 76.7% (95% CI: 59.1–88.2), neck at 73.3% (95% CI: 55.6–85.8) and wrist/hand at 60.0% (95% CI: 42.3–75.4). In the previous seven days, 21 drivers (70.0%; 95% CI: 52.1–83.3) presented complaints in at least one body region, with shoulder (53.3%; 95% CI: 36.1–69.8) and upper/lower back (50.0%; 95% CI: 33.2–66.8) predominating, followed by elbow/forearm (30.0%), neck (23.3%) and wrist/hand (20.0%). The median number of symptomatic regions was 5 (IQR: 3.25–6; 25th and 75th percentiles by linear interpolation) for the previous 12 months and 2 (IQR: 0–3) for the previous seven days (Table 2; Figure 1).

Table 2. Prevalence of musculoskeletal symptoms by body region according to the Nordic Questionnaire (n = 30).

Body region	12 months n (%)	95% CI	7 days n (%)	95% CI
Upper / lower back	24 (80.0)	62.7–90.5	15 (50.0)	33.2–66.8
Elbow / forearm	24 (80.0)	62.7–90.5	9 (30.0)	16.7–47.9
Shoulder	23 (76.7)	59.1–88.2	16 (53.3)	36.1–69.8
Neck	22 (73.3)	55.6–85.8	7 (23.3)	11.8–40.9
Wrist / hand	18 (60.0)	42.3–75.4	6 (20.0)	9.5–37.3
Knees	16 (53.3)	36.1–69.8	3 (10.0)	3.5–25.6
Hips / thighs	10 (33.3)	19.2–51.2	0 (0.0)	0.0–11.4
Ankles / feet	0 (0.0)	0.0–11.4	0 (0.0)	0.0–11.4
≥ 1 body region	30 (100.0)	88.6–100.0	21 (70.0)	52.1–83.3
Symptomatic regions per driver, median (IQR)	5 (3.25–6)	—	2 (0–3)	—

Note. n = absolute frequency; % = prevalence. 95% CI calculated using the Wilson method for a binomial proportion. IQR = interquartile range (25th and 75th percentiles calculated by linear interpolation).

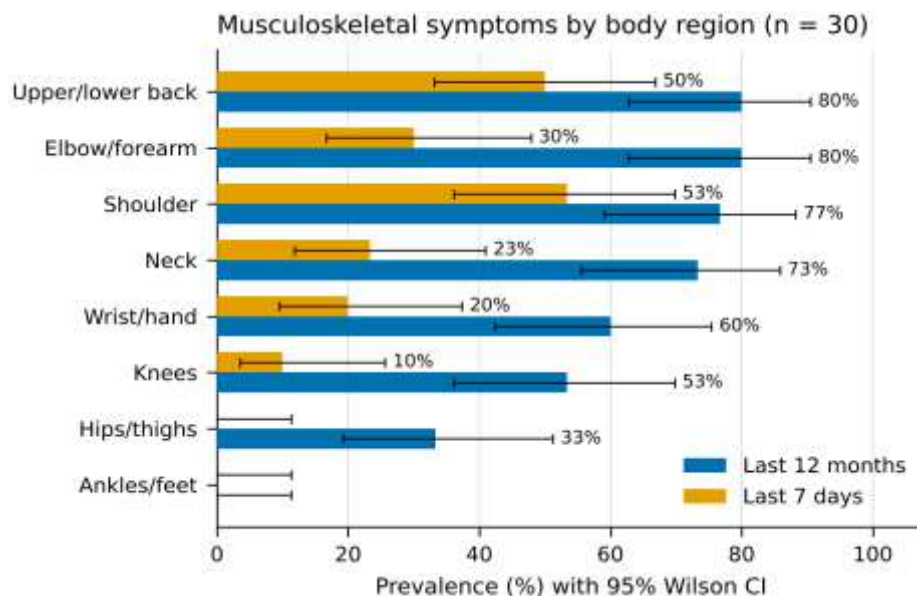


Figure 1. Prevalence of musculoskeletal symptoms by body region in the previous 12 months and previous 7 days (n = 30). Error bars represent the Wilson 95% CI.

3.3. Postural ergonomic risk

Postural assessment using RULA showed that all 30 drivers (100.0%; 95% CI: 88.6–100.0) had a maximum score corresponding to action level 3 (17 drivers with a score of 5 and 13 with a score of 6), with a median of 5 (Q1–Q3: 5–6; range: 5–6). According to the method's interpretation, these results indicate the need to investigate postural conditions and consider changes in the near term. In turn, REBA classified 24 drivers (80.0%; 95% CI: 62.7–90.5) at medium risk level (score 4: 6 drivers; 5: 11; 6: 7) and 6 (20.0%; 95% CI: 9.5–37.3) at high risk level (score 8). The median maximum REBA score was 5 (Q1–Q3: 5–6; range: 4–8). Together, both methods identified postural exposure requiring ergonomic attention, although their results should be interpreted in a complementary manner and not as directly equivalent scales (Table 3; Figure 2).

3.4. Occupational fatigue

Assessment using the Yoshitake questionnaire showed a mean total score of 13.00 ± 5.88 points (95% CI: 10.80–15.20), with a median of 13 points (IQR: 9–18) and a range of 1 to 26. By dimension, Group I, related to drowsiness and heaviness symptoms, had a mean of 5.70 ± 2.42 points; Group II, related to difficulty concentrating, recorded 3.47 ± 2.61 points; and Group III, corresponding to physical projection of deterioration, had 3.83 ± 1.91 points. The total score showed a distribution compatible with normality according to the Shapiro–Wilk test ($W = 0.9819$; $p = 0.8737$). The internal consistency of the 30 items was adequate (Cronbach's $\alpha = 0.831$) (Table 3; Figure 3).

Table 3. Ergonomic risk level according to RULA and REBA and distribution of occupational fatigue symptoms according to the Yoshitake questionnaire ($n = 30$).

Instrument / dimension	Category or statistic	Result	95% CI
RULA (maximum score per driver)			
Action level 1 (1–2)	n (%)	0 (0.0)	0.0–11.4
Action level 2 (3–4)	n (%)	0 (0.0)	0.0–11.4
Action level 3 (5–6)	n (%)	30 (100.0)	88.6–100.0
Action level 4 (7)	n (%)	0 (0.0)	0.0–11.4
Score	Median (Q1–Q3); min.–max.	5 (5–6); 5–6	—
REBA (maximum score per driver)			
Negligible (1)	n (%)	0 (0.0)	0.0–11.4
Low (2–3)	n (%)	0 (0.0)	0.0–11.4
Medium (4–7)	n (%)	24 (80.0)	62.7–90.5
High (8–10)	n (%)	6 (20.0)	9.5–37.3
Very high (≥ 11)	n (%)	0 (0.0)	0.0–11.4
Score	Median (Q1–Q3); min.–max.	5 (5–6); 4–8	—
Yoshitake (0–30)			
Group I – drowsiness and heaviness (0–10)	Mean $\pm$ SD; median (Q1–Q3)	5.70 ± 2.42 ; 5.5 (4–7.75)	4.80–6.60
Group II – difficulty concentrating (0–10)	Mean $\pm$ SD; median (Q1–Q3)	3.47 ± 2.61 ; 3.0 (2–4)	2.49–4.44
Group III – physical projection of deterioration (0–10)	Mean $\pm$ SD; median (Q1–Q3)	3.83 ± 1.91 ; 4.5 (2–5)	3.12–4.55
Total fatigue (0–30)	Mean $\pm$ SD; median (Q1–Q3)	13.00 ± 5.88 ; 13.0 (9–18)	10.80–15.20
Internal consistency (30 items)	Cronbach's α	0.831	—

Note. The unit of analysis is the driver ($n = 30$). For each participant, the highest score obtained among the two postures (P1 and P2) and both sides assessed was used. Wilson 95% CI for proportions; 95% CI of the mean (t distribution). Shapiro–Wilk normality: Group I $W = 0.966$, $p = 0.443$; Group II $W = 0.896$, $p = 0.007$; Group III $W = 0.914$, $p = 0.018$; Total $W = 0.982$, $p = 0.874$. Groups II and III do not follow a normal distribution; their medians and IQR are included in the main row.

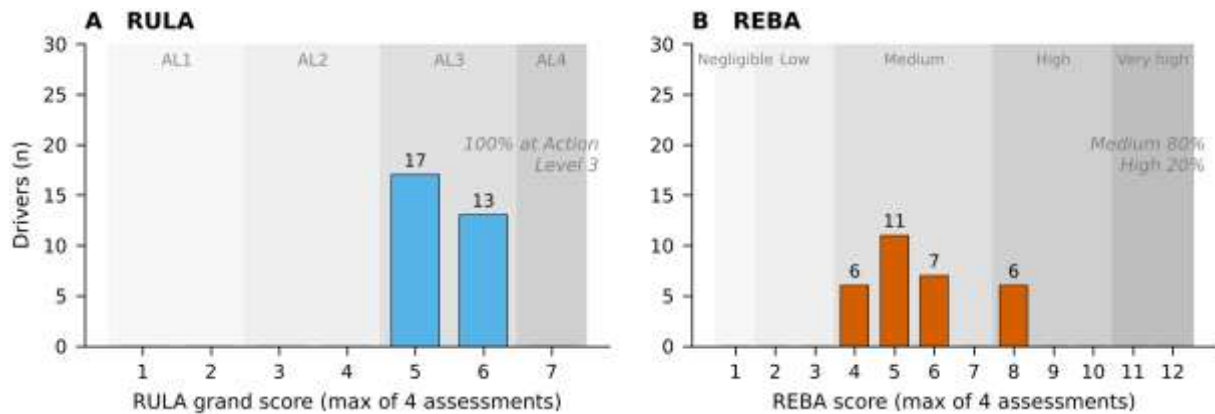


Figure 2. Distribution of maximum RULA (A) and REBA (B) scores per driver (n = 30). Shaded bands indicate the RULA action levels (AL1–AL4) and REBA risk levels.

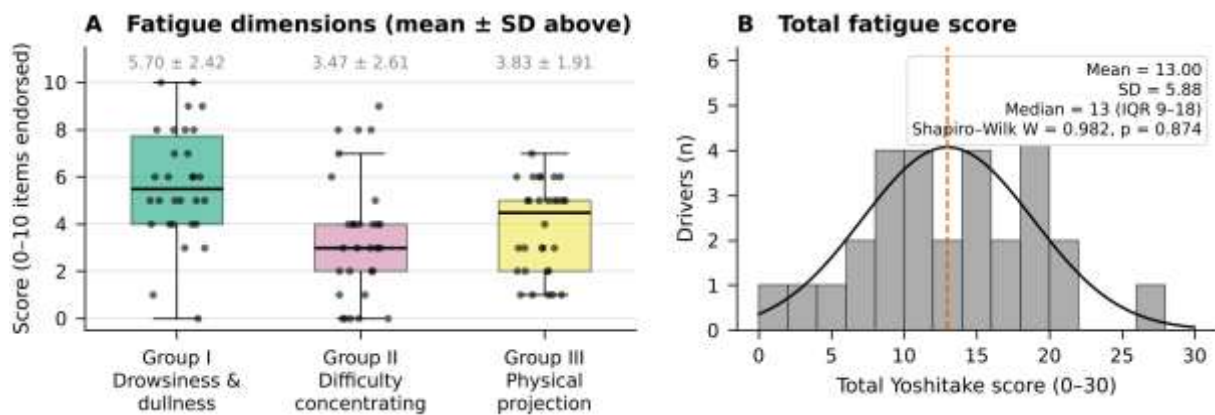


Figure 3. Subjective fatigue symptoms according to the Yoshitake questionnaire (n = 30). (A) Distribution by dimension; points represent each driver and boxes the median and interquartile range. (B) Proportion of affirmative responses to each of the 30 items, grouped by dimension.

3.5. Relationship between ergonomic risk, occupational fatigue and musculoskeletal symptoms

Analysis using Spearman's correlation coefficient revealed no statistically significant associations between the maximum scores obtained through RULA and REBA and the occupational fatigue dimensions assessed by the Yoshitake questionnaire ($p > 0.05$). For total fatigue, RULA showed a very weak positive correlation ($\rho = 0.187$; $p = 0.323$), while REBA showed a weak positive correlation ($\rho = 0.228$; $p = 0.226$). Among the Yoshitake dimensions, the highest coefficient corresponded to the relationship between REBA and Group III ($\rho = 0.317$; $p = 0.088$), although this association also did not reach statistical significance. Consequently, in the sample analyzed, no sufficient statistical evidence was found for a monotonic association between higher postural risk scores and higher occupational fatigue scores.

No statistically significant association was observed between the total occupational fatigue score and the number of body regions with musculoskeletal symptoms either. For symptoms reported during the previous 12 months, a very weak positive correlation was obtained ($\rho = 0.161$; $p = 0.394$), while for symptoms in the previous seven days the correlation was equally positive and very weak ($\rho = 0.192$; $p = 0.310$). Additionally, comparisons of total fatigue scores between drivers with and without symptoms in each body region, using the Mann–Whitney U test, showed no statistically significant differences in any period either: at 12 months, the largest difference corresponded to the upper/lower back region (medians 14.0 versus 6.0 points in 24 and 6 drivers; $U = 99.5$; $p = 0.161$) and in the remaining computable regions p ranged from 0.417 to 0.917; at 7 days, p ranged from 0.156 to 1.000 (Table 4; detail by region in Table S1 of the supplementary material). This does not mean that the drivers do not have fatigue or musculoskeletal risk; what it indicates is that, in this sample of 30 drivers, no sufficient statistical evidence was found that a higher fatigue score was associated with a greater number of symptomatic regions.

3.6. Associated sociodemographic and occupational factors

After adjustment for multiple comparisons using the Benjamini–Hochberg procedure over the predefined family of 80 tests, age was positively associated with the number of symptomatic body regions in the previous 12 months ($\rho = 0.648$; $q = 0.004$) and in the previous seven days ($\rho = 0.813$; $q < 0.001$). Similarly, years of experience as a professional driver were positively associated with the number of symptomatic regions at 12 months ($\rho = 0.614$; $q = 0.008$) and seven days ($\rho = 0.535$; $q = 0.031$). Age ($\rho = -0.588$; $q = 0.013$) and professional experience ($\rho = -0.546$; $q = 0.029$) showed negative associations with the maximum REBA score; company tenure showed correlations in the same direction with both outcomes ($\rho = 0.481$ and $\rho = -0.476$) that did not reach the significance threshold after adjustment ($q = 0.063$). Regarding occupational fatigue, perceived vibration intensity showed a moderate positive association with the total Yoshitake score ($\rho = 0.526$; $q = 0.033$), while the number of days worked per week showed a moderate negative association ($\rho = -0.504$; $q = 0.045$). None of the dichotomous factors evaluated (physical activity, sufficient rest, vibration perception) maintained significant associations after adjustment; in the unadjusted analysis, drivers who perceived vibration ($n = 27$) had higher total fatigue than those who did not ($n = 3$; medians 14.0 versus 6.0; $U = 75.0$; $p = 0.018$; $q = 0.114$). Due to the cross-sectional design of the study, these results represent statistical associations and not causal relationships. The complete correlation matrix is presented in Figure 4, the full list of 80 tests in Table S2 of the supplementary material and the significant associations are illustrated in Figure 5.

Table 4. Bivariate associations between ergonomic risk, occupational fatigue, musculoskeletal symptoms and sociodemographic and occupational factors ($n = 30$).

Set / variables	Statistic	Value	p	q (BH)
(i) Ergonomic risk vs. fatigue				
RULA max. – Total fatigue	ρ Spearman	0.187	0.323	—
RULA max. – Group I	ρ Spearman	0.122	0.522	—
RULA max. – Group II	ρ Spearman	0.138	0.468	—
RULA max. – Group III	ρ Spearman	0.127	0.504	—
REBA max. – Total fatigue	ρ Spearman	0.228	0.226	—
REBA max. – Group I	ρ Spearman	0.255	0.174	—
REBA max. – Group II	ρ Spearman	0.027	0.888	—
REBA max. – Group III	ρ Spearman	0.317	0.088	—
(ii) Fatigue vs. musculoskeletal symptoms				
Total fatigue – Symptomatic regions 12 months	ρ Spearman	0.161	0.394	—
Total fatigue – Symptomatic regions 7 days	ρ Spearman	0.192	0.310	—
Total fatigue by upper/lower back symptom, 12 months (yes, $n = 24$ vs. no, $n = 6$)	Mann–Whitney U	$U = 99.5$; medians 14.0 vs. 6.0	0.161	—
Total fatigue by symptom in remaining regions, 12 months (6 comparisons)	Mann–Whitney U	Table S1	0.417–0.917	—
Total fatigue by symptom per region, 7 days (6 computable comparisons)	Mann–Whitney U	Table S1	0.156–1.000	—
(iii) Sociodemographic and occupational factors (family of 80 tests; $q < 0.05$ after BH)				
Age – Symptomatic regions 7 days	ρ Spearman	0.813	< 0.001	< 0.001

Set / variables	Statistic	Value	p	q (BH)
Age – Symptomatic regions 12 months	ρ Spearman	0.648	< 0.001	0.004
Driving experience – Regions 12 months	ρ Spearman	0.614	< 0.001	0.008
Age – REBA max.	ρ Spearman	−0.588	< 0.001	0.013
Driving experience – REBA max.	ρ Spearman	−0.546	0.002	0.029
Driving experience – Regions 7 days	ρ Spearman	0.535	0.002	0.031
Perceived vibration intensity – Total fatigue	ρ Spearman	0.526	0.003	0.033
Days worked/week – Total fatigue	ρ Spearman	−0.504	0.005	0.045
Vibration perception (yes, $n = 27$ vs. no, $n = 3$) – Total fatigue (non-significant after BH)	Mann–Whitney U	$U = 75.0$; medians 14.0 vs. 6.0	0.018	0.114

Note. Sets (i) and (ii) correspond to the stated hypothesis and are interpreted with $p < 0.05$ without adjustment. Set (iii) comprises a predefined family of 80 exploratory tests (13 quantitative/ordinal factors $\times$ 5 outcomes = 65 Spearman + 3 dichotomous $\times$ 5 outcomes = 15 Mann–Whitney); q -values were obtained by the Benjamini–Hochberg procedure applied to this family. Only significant results ($q < 0.05$) and the vibration perception comparison are shown; the full list of 80 tests is provided in Table S2 of the supplementary material. ρ = Spearman; U = Mann–Whitney.

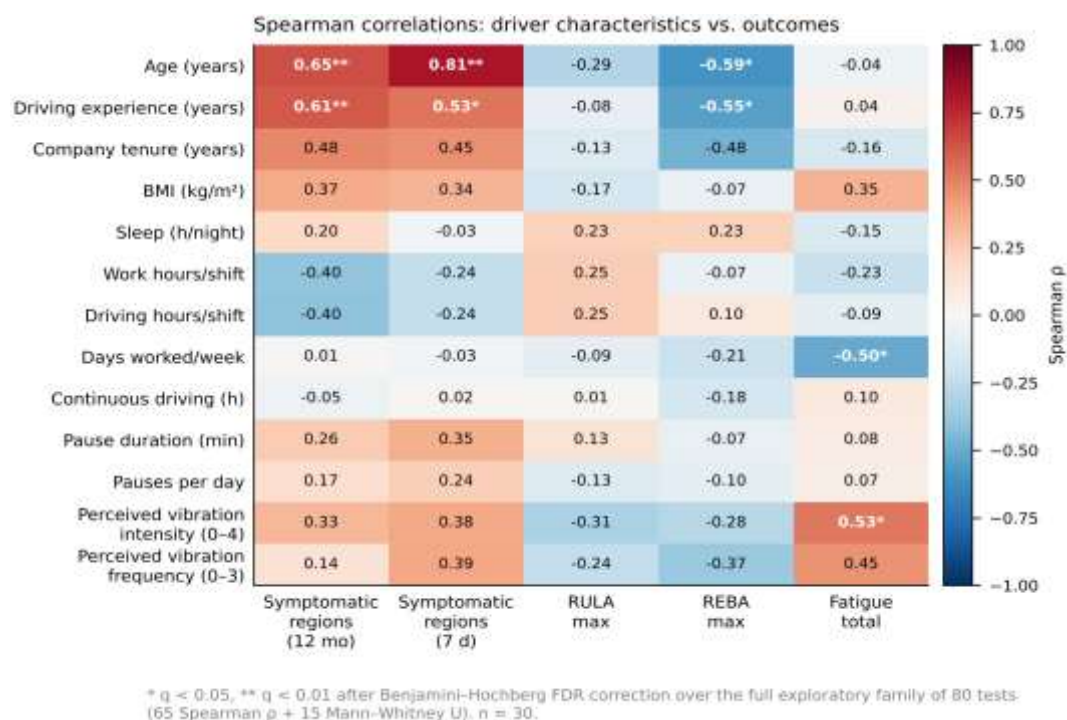


Figure 4. Spearman correlation matrix between sociodemographic and occupational factors (rows) and study outcomes (columns), $n = 30$. Asterisks indicate significance after Benjamini–Hochberg correction ($q < 0.05$) over the predefined family of 80 tests (65 Spearman correlations + 15 Mann–Whitney U tests = 80 tests).

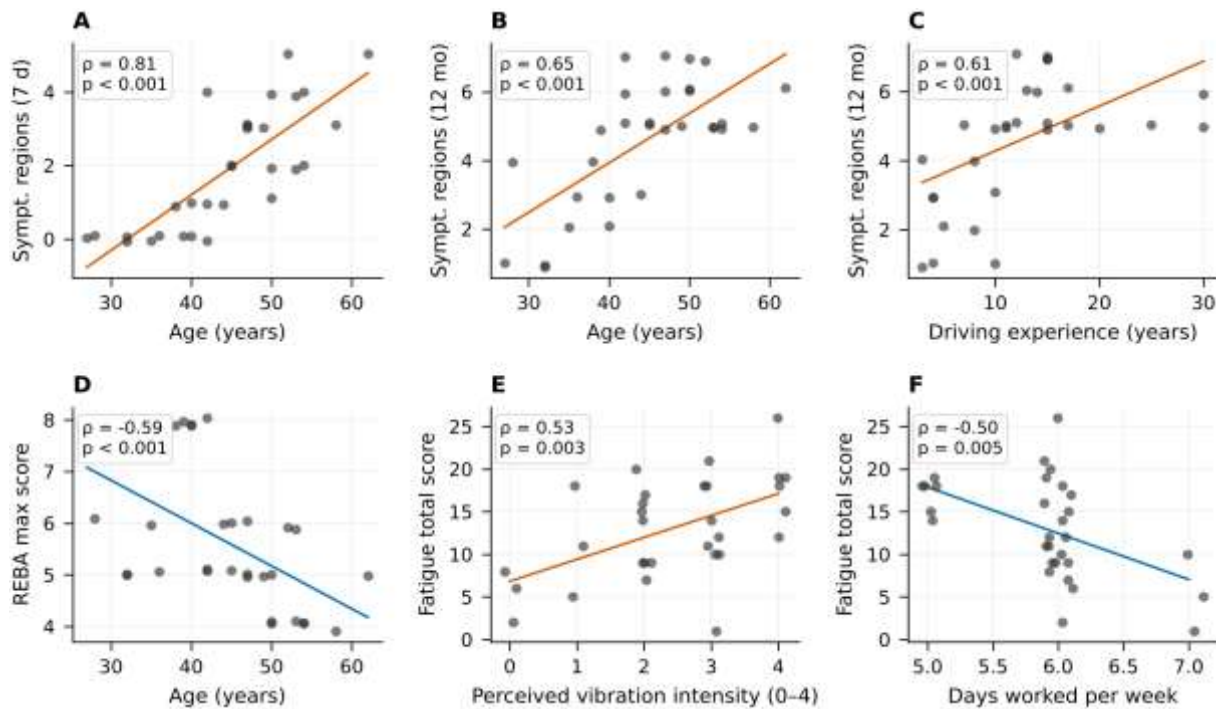


Figure 5. Significant associations after adjustment for multiple comparisons ($n = 30$). (A–C) Age and driving experience versus the number of symptomatic regions. (D) Age versus maximum REBA score. (E) Perceived vibration intensity versus total fatigue. Each point represents one driver; lines show the LOESS trend and 95% CI of the mean; ρ and q correspond to the Benjamini–Hochberg-adjusted Spearman correlation.

4. DISCUSSION

4.1. Musculoskeletal symptom burden

The results show that musculoskeletal symptoms constitute a relevant problem in the study group. All drivers reported complaints in at least one body region during the previous 12 months and seven out of ten also reported them in the previous seven days. The burden was not concentrated in a single area: the median was five symptomatic regions in the annual period. The highest prevalences were localized in the upper/lower back and elbow/forearm (80.0%), followed by shoulder (76.7%) and neck (73.3%). This pattern is consistent with what has been described in professional drivers, where the back, neck and shoulders consistently appear among the most affected regions. In a cross-sectional study of bus drivers assessed with the same Nordic Questionnaire, Kasemsan et al. (2021) found annual prevalences of 81.9% for neck and 80.7% for back, and a weekly prevalence of 53% for the dorsal region, figures very close to those observed in the present study; in Portuguese drivers, Silva et al. (2025) reported 68.3% in the lumbar region and 57.2% in the neck, and in southern India Thangamuthu et al. (2025) an overall prevalence of 65.8% with lumbar predominance. Likewise, the reviews by Joseph et al. (2020, 2023), Pickard et al. (2022) and the meta-analysis by Makki et al. (2025), which estimated an overall prevalence of 73.9%, indicate a high burden of musculoskeletal pain in this occupation. Although the figures are not directly interchangeable due to differences between populations, routes, vehicles and instruments, the coincidence in the affected regions supports the occupational relevance of the finding.

The multi-site nature of the condition deserves particular attention. In 1,792 bus drivers in Shenzhen, Wang et al. (2025) observed that the prevalence of MSDs in two or more regions (59.3%) was almost six times higher than in a single region (10.0%), and that multi-site MSDs, unlike single-site ones, were consistently associated with occupational stress, poor sleep quality and shifts exceeding 40 hours per week. In the present study, the median of five affected regions in a context of 12-hour shifts, six days per week, breaks of only 5 minutes every 3 hours of continuous driving and a median of 6 hours of sleep that 87% of the drivers considered insufficient is compatible with this profile. The mean BMI in the obesity range constitutes an additional factor: in 231 urban transport drivers in Barranquilla, Mendiñeta-Martínez et al. (2019) documented greater

frequency of musculoskeletal complaints and lower physical fitness in those with BMI above 25 kg/m². The prevalence of symptoms in the elbow/forearm (80.0%), unusually high compared to other studies, could be related to the characteristics of the assessed route segment, which combines slopes, curves and frequent stops and demands repeated steering wheel maneuvers and door controls; this explanation is hypothetical, was not evaluated in the present study and requires verification with upper limb biomechanical recordings.

4.2. Postural assessment

The postural assessment provides a second element for understanding this symptom burden. RULA placed all 30 participants at action level 3, while REBA classified 80.0% at medium risk and 20.0% at high risk. These results should not be interpreted as disease diagnoses but rather as indicators that the postures observed during driving require review and improvement measures. Driving requires maintaining a seated posture for prolonged periods and combines repetitive upper limb movements with trunk and neck adjustments to control the vehicle and attend to road conditions. Pickard et al. (2022) identified among the recurrent factors of musculoskeletal disorders in drivers prolonged sitting shifts, vehicle ergonomics, postures and vibration, and the review by Mendes et al. (2021) described in bus drivers the co-occurrence of postural demands and mechanical vibration as combined exposures. Concordantly, Joseph et al. (2023) found strong evidence for the causal relationship between awkward postures and whole-body vibration and musculoskeletal disorders in professional drivers. The RULA scores between 4 and 7 observed in Portuguese drivers using inertial motion capture (Silva et al., 2025) are comparable to those obtained here and suggest that medium-to-high postural exposure is inherent to urban bus driving.

4.3. Postural risk, fatigue and symptoms: absence of association

An important aspect is that the simultaneous presence of postural risk, musculoskeletal symptoms and fatigue did not translate into a direct statistical association among all these variables. The maximum RULA and REBA scores were not significantly associated with total fatigue or the Yoshitake dimensions. No significant association was found between total fatigue and the number of symptomatic regions either, nor significant differences in fatigue between drivers with and without symptoms in the body regions assessed. This result does not contradict the existence of the three problems; rather, it indicates that, in this population of 30 drivers, the variation in one measure could not statistically explain the variation in the others. It should also be considered that RULA showed little variability, as all participants fell within the same action level, which reduces its ability to discriminate associations within a relatively homogeneous population.

Two methodological considerations help interpret this absence of association. First, in a population homogeneously exposed to the same task, the same vehicle type and the same route, the range restriction of the postural indices (RULA concentrated at 5–6; REBA at 4–8) drastically reduces the ability of any correlation coefficient to detect associations. Second, the observational methods RULA and REBA capture posture at selected instants and not the cumulative exposure throughout the shift. Comparisons between observational methods, conducted in industrial settings and not in driving, indicate that REBA tends to assign medium or high risk categories to most evaluated workstations and to overestimate the risk level relative to RULA and to self-reported symptoms; in 300 steelwork workers, Yazdanirad et al. (2022) found that the REBA score explained 55% of the variation in musculoskeletal symptoms measured with the Cornell questionnaire, a figure that corresponds to that study and is not extrapolable to the present population. Meanwhile, fatigue measured with Yoshitake at the end of the shift reflects the integration of multiple physical, cognitive and organizational demands. It is plausible, therefore, that fatigue in this group is more determined by shift duration, sleep quality and vibration than by instantaneous posture, as suggested by the moderate and significant association between perceived vibration intensity and total fatigue score.

4.4. Occupational fatigue and work organization

Occupational fatigue deserves an independent reading. The mean Yoshitake total score was 13.00 ± 5.88 points, with the highest scores in Group I, related to drowsiness and heaviness. No cutoff point was used to classify participants as fatigued or not fatigued, so the result should be understood as a burden of subjective symptoms and not as a diagnosis. This observation becomes relevant when considering the shift characteristics: the median was 12 hours of work and 11 hours of effective driving, while 86.7% considered their rest or sleep insufficient. These conditions are comparable to those described in bus drivers in other contexts: in Korea, Kim et al. (2018) found that the working hours of most drivers exceeded their maximum acceptable work time based on cardiovascular load, and Lee et al. (2017) documented that irregular shift patterns multiplied severe drowsiness at the wheel; in Thailand, two-thirds of intercity drivers were classified as poor sleepers, with a mean of 5.5 hours

of sleep, and nighttime or rotating shifts increased the probability of poor sleep quality up to 20-fold (Chaiard et al., 2019); in Sweden, nearly half of urban drivers reported having to fight drowsiness while driving at least twice a month (Anund et al., 2016). The literature on professional driving recognizes that shift demands, driving time, rest and psychosocial factors can coexist with musculoskeletal complaints and fatigue; therefore, their preventive approach should not be limited to posture alone.

The negative association between the number of days worked per week and fatigue, although statistically significant, is counterintuitive and should be interpreted with caution. A possible, strictly hypothetical explanation is a healthy worker effect: drivers who tolerate seven-day shifts may be precisely those with lower vulnerability to fatigue, while those who report greater fatigue may have reduced their number of working days. In this study, fatigue tolerance and reasons for reducing working days were not measured, so this explanation was not evaluated and the result should not be interpreted as evidence that working more days reduces fatigue. With only 30 participants and little variability in this variable, given that most work six days, this finding requires replication.

4.5. Age, experience and symptom burden

The exploratory analysis allowed identifying associations that provide additional information. After controlling for multiple comparisons using Benjamini–Hochberg, age was positively related to the number of symptomatic regions at both 12 months ($q = 0.648$) and seven days ($q = 0.813$). Driving experience showed the same direction of association: $q = 0.614$ at 12 months and $q = 0.535$ at seven days. These results are compatible with recent literature that has found associations between age, driving experience and low back pain; however, the systematic review by Joseph et al. (2023) qualified the causal evidence for age and driving years as inconclusive, and Pickard et al. (2022) noted that, while four studies identified drivers over 45 as the highest risk group, two studies in urban bus drivers found the opposite, with greater risk in those under 40. In Portuguese drivers, Silva et al. (2025) found no correlation between age or BMI and pain intensity. Therefore, the findings of the present study should be understood as associations within this population and not as proof that age or tenure produce the symptoms.

Negative associations of age and experience with the maximum REBA score were also observed. These relationships should not be interpreted as a protective effect. A possible methodological explanation is that REBA represents the postures of greatest compromise identified in a limited driving recording and not the entire cumulative exposure over years of work. More experienced drivers may adopt different postural strategies during the observed segment without this eliminating cumulative exposure.

Two non-exclusive interpretations, both hypothetical and not measured in this study, complement this explanation. On one hand, more experienced drivers may have developed adaptive adjustments, such as seat regulation, trunk support or reduced cervical flexion, that lower the observational score. On the other hand, the presence of pain could induce protective postures that, although less demanding from the REBA perspective, are not necessarily biomechanically optimal in the long term. It should be noted that a relatively lower REBA score does not imply absence of risk: all drivers, regardless of their age, were classified at medium or high risk. In any case, the result underscores that the instantaneous postural score and the cumulative symptom burden are distinct constructs, and that a lower relative postural risk in an older driver should not be interpreted as absence of musculoskeletal risk. These interpretations require studies with larger sample sizes, repeated observations and, if possible, objective exposure measurements before drawing conclusions.

4.6. Perceived vibration

Perceived vibration was particularly relevant. Of the participants, 90.0% reported perceiving vibrations transmitted by the vehicle and its intensity was positively associated with total fatigue ($q = 0.526$; $q = 0.033$). This result is consistent with the importance the literature attributes to whole-body vibration in occupational driving. Pickard et al. (2022) repeatedly identified vibration among the factors associated with musculoskeletal disorders, Joseph et al. (2023) reported strong evidence for its relationship with these disorders, and the review by Mendes et al. (2021) concluded that bus drivers' exposure to mechanical vibration in their work routine should be considered a risk factor for low back pain, especially when combined with inadequate postures that amplify its transmission. A meta-analysis of 20 studies estimated that occupational exposure to whole-body vibration is associated with a higher prevalence of low back pain (pooled OR = 2.17; 95% CI: 1.61–2.91) and sciatica (OR = 1.92; 95% CI: 1.38–2.67), with a 1.5-fold higher risk in workers exposed to high versus low vibration levels (Burström et al., 2015), and in the prospective VIBRISKS cohort of professional drivers, internal lumbar load measures were better predictors

of the onset of lumbar disorders than external exposure metrics (Bovenzi et al., 2017). However, in this study vibration was self-reported and not measured by accelerometry in accordance with ISO 2631, and subjective perception does not equate to an exposure dose. Consequently, the finding does not allow quantifying a dose or asserting that technical limits were exceeded; it does justify considering a future instrumental vibration measurement in the vehicles and routes evaluated.

4.7. Synthesis, strengths and limitations

Overall, the descriptive results confirmed a high frequency of musculoskeletal symptoms and relevant postural exposure according to RULA and REBA; however, hypothesis testing did not support it: no statistically significant association was demonstrated between higher postural scores and greater fatigue, nor between fatigue and the number of symptomatic regions, and the coexistence of high prevalences does not in itself constitute evidence of an association between postural risk, symptoms and fatigue. It should be noted that the direct association between postural scores and the number of symptomatic regions was not part of the predefined analysis sets and was not examined. This suggests that the observed problem is multifactorial and that its explanation does not depend on a single variable. Prevention should integrate adjustments to the driving workstation, review of seat and controls, breaks and recovery during the shift, postural education and vibration assessment, in addition to musculoskeletal symptom monitoring.

Among the main limitations are the cross-sectional design, which prevents establishing temporality or causality; the study population size ($n = 30$), corresponding to the universe of a single cooperative and a single route, which limits generalization to other cooperatives, routes or cities and produces wide confidence intervals; the use of self-reported questionnaires for symptoms, fatigue and vibration, susceptible to recall or perception bias; self-reported weight and height; the postural assessment based on audiovisual recordings of defined periods, which may not represent all the variability of a shift and which was performed by a single evaluator, with intra-observer agreement control but without inter-observer assessment; the homogeneity of exposure, which restricted the range of postural indices; the absence of a validated cutoff point for the Yoshitake questionnaire for this version of the instrument in the study population, which prevented estimating fatigue prevalence; and the exclusively male composition of the group, which reflects the reality of the sector but prevents exploring sex-based differences. As strengths, the entire driver population of the cooperative was assessed with 100% participation, recognized instruments comparable to the international literature were used, each driver was assessed as the unit of analysis, symptom, posture and fatigue measures were combined under actual driving conditions on a standardized segment, the fatigue questionnaire was administered at the end of the shift and Wilson confidence intervals and a multiple comparisons adjustment over a predefined test family were applied, appropriate for small samples and exploratory analyses. These elements allow constructing a useful baseline for guiding interventions and future research in public transport drivers in Quito.

From a practical perspective, the results point to the following priority actions: evaluation and ergonomic adjustment of the driving workstation, review of shift organization with special attention to break duration and the possibility of active breaks with mobility exercises, instrumental measurement of whole-body vibration in the fleet and incorporation of a periodic surveillance program for musculoskeletal symptoms and fatigue with preferential attention to older and more experienced drivers. Given that sleep quality and duration mediate a substantial part of the effect of occupational stress on multi-site MSDs (Wang et al., 2025), interventions on schedules and rest could have an impact that transcends fatigue. Future research should expand the sample to multiple cooperatives and routes in the city, adopt longitudinal designs, incorporate objective measurements of vibration and cumulative postural load using inertial sensors and validate a cutoff point for the Yoshitake questionnaire in Spanish-speaking drivers.

5. CONCLUSIONS

A high burden of musculoskeletal symptoms was identified in the 30 drivers assessed: 100% reported complaints in at least one region during the previous 12 months and 70.0% during the previous seven days. The upper/lower back, elbow/forearm, shoulder and neck regions concentrated the highest prevalences, with a multi-site pattern of five affected regions at the median.

The ergonomic assessment revealed postural conditions requiring attention. All drivers were classified at RULA action level 3, while REBA classified 80.0% at medium risk and 20.0% at high risk. These results justify reviewing the driving workstation and the postures adopted during the task.

Occupational fatigue showed a mean total Yoshitake score of 13.00 ± 5.88 , with the highest scores in the drowsiness and heaviness dimension. This result describes subjective fatigue symptoms and should not be used as a diagnosis, as no validated cutoff point was applied.

No sufficient statistical evidence was found for an association between the maximum RULA/REBA scores and occupational fatigue, nor between total fatigue and the number of regions with musculoskeletal symptoms. Therefore, the initial hypothesis was not globally supported by the analyses conducted in this population, which could be related to the homogeneity of exposure and the instantaneous nature of the postural indices.

Age and driving experience were associated with a greater number of symptomatic regions after adjustment for multiple comparisons over the complete family of exploratory tests. Likewise, greater perceived vibration intensity was related to higher fatigue scores. These associations do not establish causality but allow identifying variables that should be considered in surveillance and prevention.

The results provide a baseline for proposing preventive measures in the study population: evaluation and ergonomic adjustment of the driving workstation, review of breaks and recovery during extended shifts, periodic monitoring of musculoskeletal symptoms and fatigue, and technical assessment of whole-body vibration. Future research should incorporate a larger sample, longitudinal follow-up and instrumental vibration measurements.

Declarations

Ethics approval and consent. The research topic was approved by Resolution UTN-FP-CD-2026-007, dated January 9, 2026, of the Honorable Board of Directors of the Graduate School of the Universidad Técnica del Norte, and the study received written authorization from the transport cooperative. All participants provided written informed consent.

Data availability. The anonymized participant-level data ($n = 30$; drivers_tidy.csv file, 34 variables) and the Python analysis code (01_prepare_data.py, 02_figures.py and 03_recheck_v3.py), which reproduce all tables and figures in the manuscript, are provided as supplementary material and are available upon reasonable request to the corresponding author, subject to authorization from the participating cooperative.

Conflicts of interest. The lead author is employed in the public transport sector; the participating cooperative had no involvement in the study design, data analysis or the decision to publish. The authors declare no other conflicts of interest.

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Author contributions (CRediT). T. L. Merchán Rosero: conceptualization, methodology, investigation, data collection, formal analysis, original draft writing. J. V. Medrano Aulestia: supervision, methodology, validation, review and editing. K. Sango Calo: supervision, methodology, review and editing. All authors approved the final version of the manuscript.

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