

ANALYSIS OF PHYSICAL ACTIVITY AS A MEDIATOR BETWEEN NON-ERGONOMIC POSITION OF UPPER BODY SEGMENTS AND MUSCULOSKELETAL HEALTH IN BUS DRIVERS

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Abstract:

The number of injuries and accidents at the workplace are constantly rising, and the most pronounced injuries are related to the musculoskeletal health. Numerous studies have revealed that city bus drivers have a high incidence of musculoskeletal pain. The aim of this study was to determine whether physical activity levels might be a mediator between the non-ergonomic position of the body's upper segments and musculoskeletal health in professional bus drivers. The study protocol included the assessment of participants' musculoskeletal health using the Örebro Musculoskeletal Pain Questionnaire, assessment of the non-ergonomic position of the upper body segments when seated by means of the Rapid Upper Limb Assessment, and measuring of the level of physical activity using the Yamax 200 pedometer. The sample consisted of 115 bus drivers, from 40 to 55 years of age, with a minimum work service of 15 years. The relationships among variables were tested using the Spearman correlation coefficient and the Wilcoxon rank sum test to include the selected variables in the multivariate linear regression model. The Box-Cox test indicated the need for logarithmic transformation of the ÖMPQ results used to measure musculoskeletal health, so a log-linear model was used in the regression analysis. The normality of the distribution of the residual regression models was tested by the Shapiro-Wilk test. The main findings of this study indicate that 95.6% of participants reported the presence of musculoskeletal pain and in 24.4% of them a very high risk of the musculoskeletal disorder was observed, which indicated the need for urgent changes. The average number of steps per day was 5,090.8. The physical activity proved (obtained by the regression analysis) as a mediator between the non-ergonomic position of the upper body segments and musculoskeletal health ($p=.027$). The obtained data may serve as an important argument for designing future public health and kinesiology interventions for the improvement of the health of professional bus drivers.

Key words: ergonomics, driver's workplace, health, walking

Introduction

Musculoskeletal health problems are considered to be one of the important groups of disorders that are fully or partially caused by unfavourable working conditions such as repetitive movements, repetitive application of force, static and non-ergonomic body posture and vibrations (NIOSH, 2014) and they often depend on the type of occupation. The available data show that 85% of nurses, 86% of tractor drivers and 83% of bus and truck drivers report disorders in their musculoskeletal system (NIOSH, 2014). Almost 40 years ago, Backman (1983) identified three key categories of health

disorders in bus drivers, namely: cardiovascular diseases, gastrointestinal disorders, and musculoskeletal problems. Some of the studies researched only the presence of musculoskeletal pain in bus drivers, without possible impacts of risk factors, and the results showed that about 61% of respondents experienced back pain, about 52% had cervical pain, 48% experienced shoulder pain, 35% had pain in the knee/thigh, and somewhat less than 20% experienced pain in other parts of the body (Grace & Peggo, 2007).

However, some studies indicate the possible reasons for the occurrence of musculoskeletal

pain, so they mention the occurrence of localized fatigue of the *erector spinae* muscle, which was observed in bus drivers during prolonged non-ergonomic sitting, as well as the lack of physical activity and ergonomic and psychosocial conditions (Casagrande & Ferreira, 2022; Krogh-Lund & Voss, 1989).

Studies evaluating the non-ergonomic position while sitting have shown that when, due to the workstation discomfort, the body is bent, tilted to one side, twisted in flexion and strained for more than four hours; all these can increase the probability ratio of developing musculoskeletal pain due to the creation of mechanical strain on the spine (Alperovitch-Najenson, Katz-Leurer, et al. 2010; Bovenzi & Zadini, 1992; Bridger, Groom, Jones, Pethybridge, & Pullinger, 2002; De Vitta, et al., 2013; Keyserling, Punnet, & Fine, 1988; Massaccesi, et al., 2003; Pynt, Higgs, & Mackey, 2002).

Many authors, encouraged by these indicators, try to explain the risk and preventive factors that could be associated with musculoskeletal health.

Physical activity is one of the preventive factors whose influence has been investigated in numerous studies. Studies have shown that the respondents who had higher levels of daily physical activity also had lower levels of disorders in their musculoskeletal system (Lordan & Pakrashi, 2014; Yarandi, Koohpaei, Arsang-Jang, & Ebrahimi, 2018).

Studies conducted on the impact of physical activity and musculoskeletal health in bus drivers show that musculoskeletal pain is more common in drivers who are not physically active (Alperovitch-Najenson, Santo, et al. 2010, Katz-Leurer, Santo, Goalkeeper, & Kalichman, 2010).

Furthermore, it is important to emphasise the interrelationship between health and physical activity since many studies have established the benefits of physical activity. Thus, the US Department of Health and Human Services (1996) points out that an active and individualized lifestyle has many health benefits and that sedentary habits are associated with an increased risk of numerous chronic diseases and reduced longevity.

Based on the previous research, a study has been designed that examines physical activity as a possible mediator between musculoskeletal health and the non-ergonomic position of the upper body segments at the driver's workplace, which is also an important prerequisite for developing the guidelines for the design of future public health and kinesiology interventions aiming at preserving musculoskeletal health. To our knowledge, this is the first study of this kind dealing with this topic and therefore the results obtained are even more significant, for both science and practice. It is necessary to take the required steps to preserve the health of every human being, especially those in high-risk jobs, such as the occupation of bus drivers.

Methods

Participants

This cross-sectional study was conducted with a sample of professional bus drivers, employees of the Zagreb Electrical Tram (ZET), a public city transportation service of the Croatian capital. The study included male drivers with a minimum service experience of bus driving for ZET of 15 years and it did not include the participants who were under 40 or over 55 years of age. All the drivers were in permanent employment and capable of performing the job of bus drivers. The participants of the study were selected by a systematic random selection. Each bus driver was equally likely to be selected if they met the criteria that were predefined in this research (age, gender, and length of service). The analysis was performed on data collected from 115 bus drivers. All the respondents signed informed consent, participated in the research voluntarily and anonymously, and they could withdraw from the survey at any time.

Procedures

The study used the Örebro Musculoskeletal Pain Questionnaire (ÖMPQ), which was implemented in several scientific studies in various countries (Linton & Boersma, 2003). It was developed to determine possible risks of developing persistent back pain problems. This paper used the usual categorization proposed by Linton and Halldén (1998): ÖMPQ ≤ 90 : a low risk of long-term incapacity for work, $90 < \text{ÖMPQ} \leq 105$: a moderate risk of long-term incapacity for work, and ÖMPQ >105 : a high risk of long-term incapacity for work. The descriptive analysis of the ÖMPQ questionnaire results included the original ÖMPQ values as well as categorized values in accordance with the described procedures. In the analysis of the interrelationship of ÖMPQ results and other characteristics observed in this study, the original ÖMPQ values were used, i.e., ÖMPQ was used as a continuous variable so as not to lose some of the information that this variable contained, which is inevitable during the categorization process.

To assess the impact of non-ergonomic working conditions on the musculoskeletal system, the method for assessing the condition of the upper limbs was used (Rapid Upper Limb Assessment—RULA). RULA was developed as a measuring instrument to assess the exposure of the workers to non-ergonomic risk factors associated mainly with disorders of the upper segments of the musculoskeletal system that are important in bus drivers. The level of musculoskeletal risk is divided into four score groups, based on points (Mirmohammadi, Mehrparvar, Olia, & Mirmohammadi, 2012): 1–2 points: a negligible risk, nothing needs to be done, 3–4 points: a low risk, a change may be necessary,

5 – 6 points: a medium risk, further research, immediate intervention needed, and 6 + points: a very high risk, urgent change needed. Also, short interviews with the drivers led to a better understanding of their tasks while driving and the complexity of the job itself.

In this study, physical activity levels of bus drivers were measured using a pedometer that measured the number of steps made in a given time, so exclusively step-based physical activity was monitored. A Yamax 200 pedometer was used, which proved to be stable and suitable for scientific research (Schneider, Crouter, & Bassett, 2004). The respondents wore a pedometer for four days, three working days and one non-working day (due to the specifics of working hours, instead of a weekend day a day off was used) that recorded their number of steps made during the entire measurement period. For the purposes of statistical analysis, the average number of steps per day for each respondent was calculated.

Statistical analysis

The relationships among variables were tested using the Spearman correlation coefficient and the Wilcoxon rank sum test. Based on the results of these tests, variables for inclusion in the multivariate linear regression model were identified. The Box-Cox test indicated the need for logarithmic transformation of the ÖMPQ results used to measure musculoskeletal health, so that a log-linear model was used in the regression analysis. The normality of the distribution of the residual regression models was tested by the Shapiro-Wilk test and graphical review of their distribution. P-values less than or equal to 0.05 were considered statistically significant. Statistical analysis was carried out using the SAS System software package (SAS Institute Inc., North Carolina, USA).

Results

The Örebro Musculoskeletal Pain Questionnaire (ÖMPQ) indicated a moderate or high risk of long-term incapacity for work observed in almost every fifth driver (22 of them, i.e., 19.1%). A low risk of long-term incapacity for work was present in the majority of drivers (93 drivers, i.e., 80.9%) (Table 1).

The majority of respondents, 110 of them (95.6%), reported the presence of musculoskeletal pain. Observing the participants who reported pain, the lower back was the most common area of pain (81 drivers, i.e., 70.4%), followed by the neck (36 drivers, i.e., 31.3%), leg (28 drivers, i.e., 24.3%), shoulders and upper back (24 drivers, i.e., 20.9%) and arms (15 drivers, i.e., 13.0%) (Table 2). Other types of pain usually included problems with hips (seven drivers) and knees (three drivers).

The assessment of exposure of the musculoskeletal system to non-ergonomic upper body

postures (RULA) indicated that in the majority of drivers, 66 of them, i.e., 57.4%, a medium risk of the occurrence of musculoskeletal disorders was observed, i.e., the need for immediate intervention was observed; further, in 21 drivers (18.3%) a low risk was observed and in 28 drivers (24.4%) a very high risk of musculoskeletal disorder, which indicated the need for urgent changes at their workplace and of their lifestyle (Table 3).

The level of physical activity was measured by pedometers over four days (three working days and one non-working day). For each participant, an average number of steps per day was calculated. The distribution of the average number of daily steps was analysed in Table 4. The average number of steps per day amounted to 5,090.8 (2,883.3), and the median was 4,809.8 (3,424.0 – 5,937.0).

The results of the regression analysis of the physical activity as a mediator between the non-ergonomic position of the upper body segments and musculoskeletal health are presented in Table 5. The Shapiro-Wilk test indicated an approximately normal distribution of the regression model residual (p -value=.144). White's heteroscedasticity test indicated the homogeneity of the residual variance (p =.131).

Table 1. Distribution of categorized ÖMPQ values

| Risk of long-term incapacity for work | ÖMPQ value | N | % |
|---------------------------------------|-----------------|----|------|
| Low | ÖMPQ ≤ 90 | 93 | 80.9 |
| Moderate | 90 < ÖMPQ ≤ 105 | 13 | 11.3 |
| High | ÖMPQ >105 | 9 | 7.8 |

Table 2. Pain in musculoskeletal system according to the affected areas of the body

| Pain-affected area of the body | N | % |
|--------------------------------|----|------|
| Lower back | 81 | 70.4 |
| Neck | 36 | 31.3 |
| Leg | 28 | 24.3 |
| Shoulders | 24 | 20.9 |
| Upper back | 24 | 20.9 |
| Arm | 15 | 13.0 |
| Other | 14 | 12.2 |

Table 3. Distribution of RULA values

| Risk level of musculoskeletal disease | RULA | N | % |
|---------------------------------------|--------------|----|------|
| Negligible risk | RULA < 2 | . | . |
| Low risk | 3 ≤ RULA ≤ 4 | 21 | 18.3 |
| Medium risk | 5 ≤ RULA ≤ 6 | 66 | 57.4 |
| Very high risk | RULA > 6 | 28 | 24.4 |

Table 4. The indicators of the distribution of average number of steps per day

| Variable | \bar{x} | SD | Med | Q1 | Q3 | Min | Max |
|-----------------|-----------|---------|---------|---------|---------|-------|----------|
| Number of steps | 5,090.8 | 2,883.3 | 4,809.8 | 3,424.0 | 5,937.0 | 965.0 | 18,331.3 |

Note. \bar{x} = arithmetic mean; SD = standard deviation; Med = median; Q1 = first quartile; Q3 = third quartile; Min = minimum; Max = maximum.

Table 5. Regression analysis of physical activity as a mediator between non-ergonomic body position and musculoskeletal health (dependent variable is the logarithmic value of the ÖMPQ result)

| Variable | Coefficient | Exp (coefficient) | Standard error | p-value | Tolerance | Inflation of variance |
|-------------------------------------------------|-------------|-------------------|----------------|---------|-----------|-----------------------|
| Constant | 3.080 | | 0.425 | <.001 | | |
| Number of daily steps (in 000) | 0.114 | 1.121 | 0.073 | .119 | 0.031 | 32.236 |
| Posture (RULA) | 0.219 | 1.245 | 0.071 | .003 | 0.245 | 4.078 |
| Number of daily steps (in 000) * Posture (RULA) | -0.028 | 0.973 | 0.012 | .027 | 0.031 | 31.807 |

$R^2 = 0.192$; Corrected $R^2 = 0.170$.

Physical activity was shown to be a mediator between the non-ergonomic position of the upper body segments and musculoskeletal health. This was indicated by the interaction between the average number of daily steps and RULA points, which was significant ($p=.027$). This means that the effect of the upper body segments on musculoskeletal health depends on the physical activity of the drivers – in the case of those who were more physically active, the effect on musculoskeletal health was smaller (based on the ÖMPQ result) as compared to the drivers who were less physically active.

Discussion and conclusions

Our study has found a high incidence of pain in the bus drivers' musculoskeletal system, in as many as 96%, out of which 70.4% of the pain was reported in the lower back and 31% in the neck, followed by 24% of leg pain, 21% of shoulder and upper back pain, and 13% of reported pain sites were arms. The categorization of ÖMPQ values indicated a low risk of long-term incapacity for work in the majority of drivers (81%), while a moderate and high risk of long-term incapacity for work was observed in almost every fifth driver (19%). The average ÖMPQ value was 66.9. The results have shown that physical activity may be a mediator between musculoskeletal health and the non-ergonomic position of the body's upper segments.

Many other studies have also reported a high level of pain incidence in bus drivers. Thus, Netterstrom and Juel (1989) indicate in their study that the incidence of lower back pain was present in 57% of cases among bus drivers. Furthermore, a five-year study by Krause, Ragland, Fisher and Syme (1998), examining over 1,000 Californian drivers of various vehicles, identified 501 injuries to the lower back. The results of more recent studies keep

reporting a high rate of incidence of the disorder of the musculoskeletal system in bus drivers, i.e., about 55% (Pradeepkumar, Sakthivel, and Shankar, 2020).

One of the possible explanations for such a high rate of pain in the musculoskeletal system of bus drivers may be associated with uncomfortable and irregular upper segment body postures during long hours of driving. In their studies, the authors report that in bus drivers, uncomfortable/incorrect body postures and asymmetrical body positions when sitting can cause mechanical strain in the spine, and therefore, lower back and neck pain (Grace & Peggo, 2007).

In this study, the RULA method was used for the ergonomic assessment of mechanical and postural load at work the participating bus drivers were exposed to. RULA assesses the exposure of the workers to non-ergonomic risk factors related mainly to the disorders of the upper segments of the musculoskeletal system that are quite important in bus drivers. The majority of drivers (57%) had a moderate risk of developing a musculoskeletal disease, i.e., the need for immediate intervention; in 18% of drivers a low risk and in 24% of them a very high risk of developing a musculoskeletal disorder was recorded. The latter indicated the need for urgent changes. The non-ergonomic position of the upper body segments may contribute to ever greater muscle strain, higher compression on the joints and spine and higher load force on the joints involved in driving. This is precisely why it is possible that the factors such as deviations from the natural position of the body and the prolonged duration of these actions may result in a higher rate of disorders in the musculoskeletal system (Grace & Peggo, 2007; Westgaard, 2000).

Some of the authors agree that just sitting itself does not represent a risk of pain, but rather that the unnatural twisting of the body through flexion or extension, for longer than four hours, can increase the probability ratio of developing musculoskeletal pain (Casagrande & Ferreira, 2022; Lis & Black, 2007; Massaccesi, et al., 2003).

Previous studies on the level of physical activity usually used questionnaires, and by examining the available literature no research could be found in which the level of physical activity of bus drivers was determined using objective and more accurate pedometer measurements. The average number of steps per day amounted in our participants to 5,091, whereas the maximum number of steps was 18,331.3, and the minimum was 965. Considering the values of the level of physical activity, it can be concluded that the obtained values were still below the recommended level of daily physical activity that, for the population between 20 and 65 years of age, is 7,000 – 8,500 steps (Tudor-Locke, et al., 2011). Physical activity is undoubtedly an important factor in maintaining the optimal level of health as confirmed by many authors around the world (Eyler, Browson, Bacak, & Housemann, 2003; Lee & Paffenbarger, 2000; Pate, et al., 1995). It can be therefore assumed that the explanation of the high incidence of pain in 96% of the bus drivers resulted from their insufficient and inadequate physical activity (Hildebrandt, Bongers, Dul, & Kemper, 2000; Toroptsova, Benevolenskaya, Karyakin, Sergeev, & Erdesz 1995).

Krause, Rugulies, Ragland, and Syme (2004) monitored the professional bus drivers with the reported pain in their musculoskeletal system for 7.5 years. Their study provided strong evidence of physical risk factors at the workplace for the occurrence of pain. The results of that study showed that the professional bus drivers who had rated the ergonomic issues as high had a significantly higher risk of musculoskeletal disorders. They also pointed out that by correcting the ergonomic conditions, lower back pain may be reduced by 19% in all bus drivers. Addressing this issue could prevent disorders in the musculoskeletal system and reduce the occupational disabilities in this high-risk occupation and reduce significant economic expenses related to lower back pain.

Observing physical activity as a mediator between the non-ergonomic position of the upper body segments and musculoskeletal health, the results indicated statistical significance ($p=.027$) of physical activity as a mediator between ergonomics and health. This means that in the drivers who were more physically active, one may expect that the effect of a poorer posture of the upper body

segments had less impact on their musculoskeletal health (Table 5). In the research by Hildebrandt et al. (2000) the authors also concluded that stimulating physical activity can represent one of the methods of reducing musculoskeletal problems in the working population, especially in workers who spend a lot of time sitting at their workplace.

Results of our research suggest that physical activity mediates the effect of the non-ergonomic position of the upper body segments on the musculoskeletal health level; a higher level of physical activity could promote the health of the musculoskeletal system in non-ergonomic working conditions among bus drivers. Although according to the available literature, there is no research on physical activity as a mediator between the ergonomic working conditions and the health of musculoskeletal systems in professional bus drivers, the physical activity variable has been the subject of consideration in many studies.

In the present study, physical activity levels were determined using a pedometer. Using this method, enabled us to avoid possible mistakes made by the participants' subjective self-evaluation of the level of their physical activity, which is one of the advantages of this research.

This research has a limitation that should be considered when generalizing the results. The research was conducted on a convenience sample, and it is not possible to generalize the results to the population of Croatian bus drivers aged between 40 and 55 years. Only male bus drivers were surveyed in this study; however, since women have recently become involved in these occupations as well, professional female bus drivers should be included in the next research. Female drivers could have an even higher disorder incidence and pain in the musculoskeletal system due to anthropometric factors because they are smaller, and the driver's seats are designed for male drivers.

Taking into account the obtained results of this research, it is first of all necessary to make a good strategy of promoting physical activity among bus drivers as one of the possible factors for improving the health of the musculoskeletal system. Furthermore, it is necessary to program the guidelines for designing the kinesiology and public health programs that will focus on educating bus drivers about the proper upper body segment posture while driving and increasing the level of their physical activity in the form of walking and other kinesiology programs to reduce the incidence of pain in the musculoskeletal system. It is also important to emphasise that the introduction of such strategies can greatly contribute to preserving the health of the younger generations of drivers who are yet to come.

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