OCCUPATIONAL RISK FACTORS FOR CARPAL TUNNEL SYNDROME AMONG WORKING POPULATION
PROFESIONÁLNE FAKTORY PODIEĽAJÚCE SA NA VZNIKU SYNDRÓMU KARPÁLNEHO TUNELA U PRACUJÚCEJ POPULÁCIE

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ABSTRACT
Background: In the Slovak Republic, similarly as in surrounding countries, carpal tunnel syndrome is the most common occupational disease.
Aim: The purpose of the study was to evaluate occupational risk factors associated with carpal tunnel syndrome among working population.
Methods: A case–control study was designed with 112 cases and 300 controls. We studied consecutive patients with an electrophysiologically confirmed diagnosis of carpal tunnel syndrome. Univariate analysis was performed on the two groups (cases and controls) comparing them for presence of various risk factors. Multivariate analysis was carried out through the logistic regression.
Results: Job duration (odds ratio (OR) = 0.91, 95% confidence interval (CI) = 0.49 – 1.65), job rotation (OR = 0.27, 95% CI = 0.14 – 0.49), repetitive movement (OR = 18.15, 95% CI = 8.49 – 39.80) and hand-arm vibrations (OR = 3.91, 95% CI = 1.95 – 7.85) were factors significantly associated with CTS.
Conclusion: Occupational risk factors such as repetition of movements, hand-arm vibrations, lack of job rotation increase the risk of developing carpal tunnel syndrome.

Key words: Peripheral nerve disorders. Occupational diseases. Repetitiveness of movements. Job rotation. Vibrations

ABSTRAKT
Východiská: V Slovenskej republike a rovnako aj v okolitých krajinách je syndróm karpálneho tunela najčastejšia choroba z povolania.
Ciele: Cieľom štúdie bolo identifikovať profesionálne rizikové faktory podieľajúce sa na vzniku syndrómu karpálneho tunela u pracujúcej populácie.
Metódy: Bola realizovaná „case-control" štúdia so 112 prípadmi a 300 kontrolami. Skupinu prípadov tvorili pacienti s EMG potvrdeným syndrómom karpálneho tunela. Multivariantná analýza bola vykonaná prostredníctvom logistickej regresie.
Výsledky: Dĺžka pracovnej expozície (odds ratio (OR) = 0,91, 95% konfidenčný interval (CI) = 0,49 – 1,65), nedostatočná pracovná rotácia (OR = 0,27, 95 % CI = 0,14 – 0,49), repetitívne pohyby (OR = 18,15, 95 % CI = 8,49 – 39,80) vibrácie prenášané na ruky (OR = 3,91, 95 % CI = 1,95 – 7,85) boli faktory významne asociované so vznikom syndrómu karpálneho tunela.
Záver: Profesionálne rizikové faktory ako repetitívna činnosť, vibrácie prenášané na ruky, nedostatočná rotácia práce zvyšujú riziko vzniku syndrómu karpálneho tunela.

Kľúčové slová: Periférne poruchy nervov. Choroby z povolania. Repetitívnosť pohybov. Pracovná rotácia. Vibrácie

BACKGROUND

Over the last decade, the local muscle load has been on the rise not only in Slovakia but also in the surrounding countries in connection with the change in the labor supply and with increasing demands on the work performance.

In the European Union, 62 % of employees perform repetitive movements during work and 47 % of employees are exposed to forced positions [1]. As a result of scientific-technical development, a physical overload with an emphasis on small muscle groups of hands and forearms is one of the most important problem. The most common upper limb disorder is the carpal tunnel syndrome (CTS), viewed as multifactorial disease. Less than half of all cases are associated with working environment and working activities. In addition, personal factors, e.g. lifestyle characteristics, certain diseases/condition (diabetes mellitus, higher body mass index, cardiovascular diseases) are also associated with CTS [2-4].

One of the most exposed sectors in terms of repetitive strain injury (mostly CTS) is industrial production. The occupations with the most frequent occupational diseases are different from a gender perspective. For men, there are mainly auxiliary workers in mining, construction, manufacturing and repairs, and for women, mainly assembly workers employed in automotive industry [5-7].

The aim of this study was to examine the association of occupational risk factors and CTS.

METHODS

The present case-control study was performed in January 2019 to February 2020 on 112 patients (48 males, 64 females) from the Comenius University in Bratislava, Jessenius Faculty of Medicine in Martin, Clinic of Occupational Medicine and Toxicology. We studied consecutive patients with an electrophysiologically confirmed diagnosis of symptomatic CTS including hand numbness, weakness, paresthesia and mainly nocturnal pain.

As a control group, there were 300 subjects without any known signs of systemic disease or symptoms of CTS. Patients in the control group were treated at the Clinic of Occupational Medicine and Toxicology, Slovakia. We obtain a randomly selected control group.

We took into account a gender, age, dominant and the affected hand, and job duration. The age of the patient was defined as the age at the time of the diagnosis of CTS. Gender was determined from the hospital records.

Initially, we explored the associations of CTS release with repetitive movements, forced position, job rotation, work shifts, hand-arm vibrations, night work, interacting factors (temperature). All cases underwent a personal history and direct physical examination. We obtained the information from the medical records, expert opinion of the investigation of working conditions (part of the occupational diseases investigation) and through the checklist. The checklist was completed for all patients and inquired into occupational risk factors.

The monitored factors included:

- repetitive movements (cycle time of less than 30 seconds or more than 50% of the cycle time involved performing the same type of movement),
- hand-arm vibrations, using vibrations tools,
- job rotation (lack of job rotation),
- cold environment (i.e., t < 18°C),
- forced working positions of the hand, asymmetric load (i.e., flexion/extension > 70°, ulnar deviation),
- work shifts (1,2,3 - shifts operation).

All exposure variables were analysed as dichotomous (i.e., present/absent).

Statistical analysis

Univariate analysis was performed on the two groups (cases and controls) comparing them for presence of various risk factors. Student´s t-test was used for comparison between two means for quantitative variables. For the analysis of categorical risk factors of CTS, odds ratio (OR) was calculated, with a 95% confidence interval (95% CI) and evaluated using chi-square test. Multivariate analysis was carried out through logistic regression. Multivariate logistic regression was performed using CTS as the dependent variable to examine the contributions of the following independent variables. Strength of association was represented with the OR and 95% CI. Epi Info 7 and SPSS 24 were used for statistical analysis. The significance level used in all statistics was $p = 0.05$ or less.

RESULTS

There were 112 patients, 48 males (42.86 %), 64 (57.14 %) females and 300 controls (46 % males, 54 % females). The arrangement of cases and controls is shown in Table 1.

Table 1 Shape of cases and controls

Variable	Cases (n = 112)	Controls (n = 300)
Age (years), mean (SD)	52.08 (5.97)	49.60 (9.35)
Gender		
Male n (%)	48(42.86)	138(46)
Female n (%)	64 (57.14)	162 (54)

Cases and controls

Case group included 112 patients with an electrophysiologically confirmed diagnosis of symptomatic CTS also including hand numbness, weakness, paresthesia and mainly nocturnal pain. CTS was identified on 187 hands (105 right, 82 left), being mild in 93, moderate in 66, and severe in 28 (hands). Of total 112 patients, 75 (66.96 %) had bilateral CTS, 30 (26.79 %) had localization on the right hand, and only 7 (6.25 %) had it on the left. The mean age of patients was 52.08 years (SD = 5.97, range = 21 – 66). The mean daily number of worked hours was 9.61 hours (SD = 2.68). We found that the mean duration of occupational exposure was 15.65 years (SD = 12.62). The mean height was 168.55 cm (SD = 9.36) with a mean weight of 85.95 kg (SD = 16.53) and a BMI of 30.19 (SD = 4.98) kg/m^2. Of all 112 patients, we found out 106

(94.64 %) right-handed and 6 (5.36 %) left-handed persons.

Control group included 300 patients without any known signs of systemic disease or the symptoms of CTS. The mean age of persons in a control group was 49.06 years (SD = 9.36, range = 21 – 63). The mean daily number of working hours was 9.41 hours (SD = 2.52). We found that the mean duration of occupational exposure was 16.16 years (SD = 11.87). The mean height reached 170.20 cm (SD = 9.22) with a mean body weight of 77.80 kg (SD = 15.06) and BMI of 26.81 (SD = 4.59) kg/m^2.

The mean age and BMI were greater in the CTS cases compare to the control group ($p = 0.006$, $p < 0.001$) (Table 2).

Based on the Statistical classification of occupation ISCO-08, the occupations in which CTS occurred were different regarding to gender. In the female group, we recorded the most cases of disease among assemblers (23 cases).

Table 2 Comparison of quantitative variables in CTS cases and controls

Variable	Cases (n = 112)	Controls (n = 300)	p-value
Age (years), mean (SD)	52.08 (5.97)	49.60 (9.36)	**0.006**
BMI (kg/m^2), mean (SD)	30.19 (4.98)	26.8 1 (4.59)	**<0.001**
Job duration (years), mean (SD)	15.65 (12.62)	16.16 (11.87)	0.439

Legend: SD – standard deviation; Student t-test

On the other side, in the male group, we found the most cases of CTS among labourers in mining, construction, manufacturing and transport (18 cases) (Figure 1).

The result of univariate logistic regression analyses examining the relationship between occupational/workplace factors and CTS are shown in Table 3.

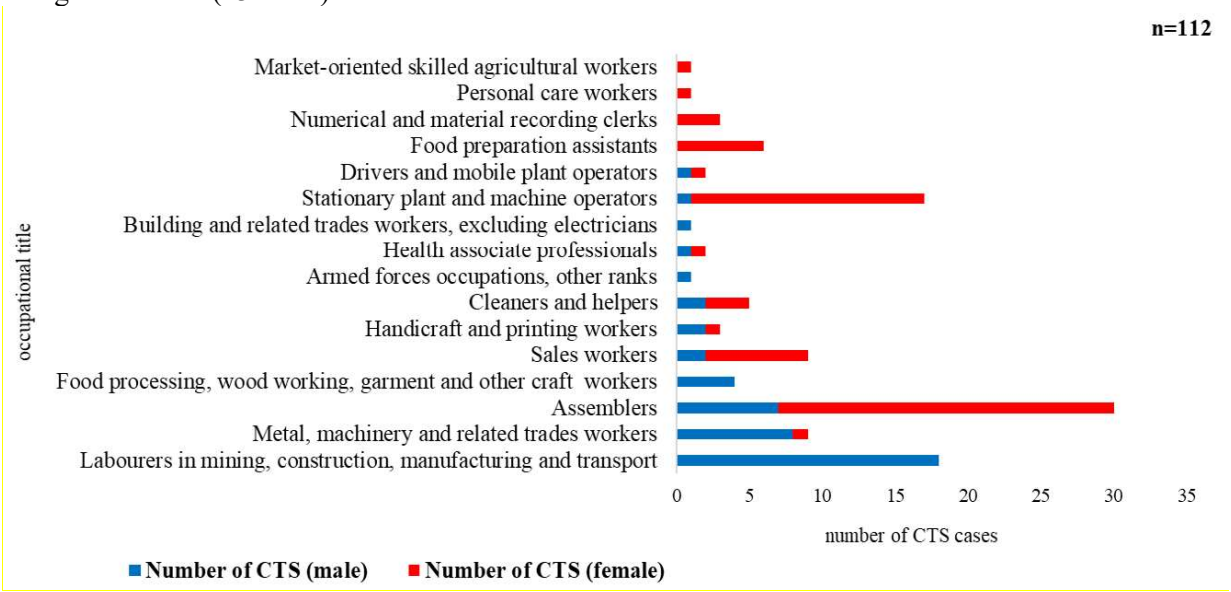

Figure 1 Occurrence of CTS according to Statistical classification of occupations ISCO-08

Table 3 Univariate odd ratio for relationship of occupational factors to CTS

Variable	Cases n = 112 (%)	Controls n = 300 (%)	OR (95% CI)	p-value
Repetitive movements	56 (50.00)	20 (6.66)	14 (7.79 – 25.15)	**<0.001**
Forced positions	49 (43.75)	57 (19.00)	3.32 (2.07 – 5.31)	**<0.001**
Job rotation	59 (52.67)	207 (69.00)	0.5(0.32 – 0.78)	**0.002**
Shifts	74 (66.07)	144 (48.00)	2.11 (1.34 – 3.32)	**0.001**
Hand-arm vibrations	54 (48.21)	42 (14.00)	5.72 (3.49 – 9.37)	**<0.001**
Night work	20 (17.85)	52 (17.33)	1.04 (0.59 – 1.83)	0.901
Cold environment	27 (24.11)	46 (15.33)	1.75 (1.03 – 2.99)	**0.038**

Legend: OR – odds ratio

Repetitive movements (OR = 14, 95% CI = 7.79 – 25.14), forced positions (OR = 3.32, 95% CI = 2.07 – 5.31), lack of job rotation (OR = 0.5, 95% CI = 0.32 – 0.78), shifts (OR = 2.11, 95% CI = 1.34 – 3.32), hand-arm vibrations (OR = 5.72, 95% CI =3.49 – 9.37) and cold environment (OR = 1.75, 95% CI = 1.03 – 2.99) are significant predictors of CTS.

When we performed multivariate logistic regression analysis, the age (OR = 1.07, 95% CI = 1.03 – 1.17), job duration (OR = 0.91, 95% CI = 0.49 – 1.65), job rotation (OR = 0.27, 95% CI = 0.14 – 0.49), repetitive movement (OR = 18.15, 95% CI = 8.49 – 39.80) and hand-arm vibrations (OR = 3.91, 95% CI = 1.95 – 7.85) were the only factors significantly associated with CTS (Table 4).

Table 4 Multivariate logistic regression analysis

Variable	OR (95% CI)	p-value
Age	1.07 (1.03 - 1.17)	**<0.001**
Gender (male/female)	0.91 (0.49 - 1.65)	0.745
Job duration	0.96 (0.94 - 0.99)	**0.007**
Shifts	2.08 (1.10 - 3.91)	**0.024**
Night work	0.64 (0.28 - 1.46)	0.289
Job rotation	0.27 (0.14 - 0.49)	**<0.001**
Repetitive movements	18.15 (8.49 - 39.80)	**<0.001**
Forced positions	1.48 (0.72 - 3.06)	0.287
Hand-arm vibrations	3.91 (1.95 - 7.85)	**<0.001**
Cold environment	0.76 (0.34 - 1.71)	0.505

Legend: OR – odds ratio

DISCUSSION

As a result of constant process of automatization, robotization, and modernization of industry in the past few years, the number of works in which small muscle groups of hands and forearms are overloaded is rising up. An average person spends approx. 1800 hours in the working environment, about half of a life in the workplace, and many years preparing for the career. Employees are exposed to various risky factors and these in turn, may have a negative impact on their health.

In the Slovak Republic, similarly as in surrounding countries, CTS is the most common occupational disease. It must be necessary to clarify impact of risky factors (occupational, nonoccupational) to CTS. Thurston [8]suggested that occupational factors are unambiguous in etiology of CTS. On the other hand, there are authors who argue that nonoccupational factors, especially the age, overweight and obesity, are the dominant factors that primarily result in development of CTS [9]. Thus, it seems, CTS is kind of multifactorial disease; therefore, one factor cannot be considered as the cause of the disease. Armstrong et al. [10] suggested that CTS should be understood as a multifactorial disease, where the conceptual model of CTS is complex. It is a combination of occupational and nonoccupational factors, which to some extent may contribute to its creation. We are along with this opinion.

The study of Maghsoudipour et al. [11] showed that almost 12 % of industrial workers were CTS. According to National health information centre of the Slovak Republic, the most exposed sectors in appearance of repetitive strain injury (mostly CTS) is industrial production. The second most common factor that occurs in the automotive industry is noise [12]. Also, in our study we recorded the most cases of diseases among female assemblers. On the other side, in the male group, we recorded the most cases of CTS among labourers employed in mining, construction, manufacturing and transport [5-7].

Our study confirms that exposure to biomechanical risky factors, such as a high perceived workload, hand-transmitted vibration, or repetitive movements directly increases the development of CTS. This finding is in agreement with several other studies [13-15].

The lack of job rotation is considered as one of the most risky factor of CTS. Roquelaure et al. [13] suggested that lack of job rotation was associated with the onset of CTS. The most important aspect is the correct planning and timing of the job rotation depending on the type of work performed (job rotation schedule). The ideal interval before the worker's training is each 2 hours and after training or implementation each 1.5 hours [15, 16]. The findings of our study confirm the association between lack of job rotation and CTS (OR = 0.27, 95% CI = 0.14 – 0.49).

In our study, the significant positive association between repetition and CTS was also found (OR = 18.15, 95% CI = 8.49 – 39.80). Our finding was consistent with the results of most published studies [13, 17-20]. In our sample, vibrations (hand-arm) was also associated with the onset of CTS, as it has been described by other authors [11]. A meta-analysis by Palmer et al. [21] also confirmed vibration tools as predictors of CTS and claim that working with vibrating tools increases the risk of occurrence by up to twice.

The observed association can be explained by an increase of interstitial fluid pressure within the carpal tunnel. An increased pressure in carpal tunnel would in turn compress its contents, which may lead to poor blood circulation, and to next damage (irreversible) of the flexor synovial cells and the median nerve synovia. As a result, is the nerve oedema, with later extensive fibrosis and demyelination of the median nerve [20]. Some studies that have focused on carpal tunnel pressure indicate that the greatest increase pressure in the canal occurs with wrist flexion or extension. Older results by Rempel et al. (1998) pointed to the fact that the position of the forearm, palm and fingers clearly participate in the development of CTS [22].

Another authors e.g. Erick et al. [23]clearly confirmed the link between the forced working positions of the upper limbs and the CTS. However, in our study forced positions was not significantly associated with CTS.

There are some limitations in this study that could be addressed in future research. First, the study focused on evaluation of occupational risk factors associated with CTS. Authors didn´t analyse the association of non-occupational factors such as lifestyle factors, pregnancy, hypothyroidism, and diabetes and CTS. The main strengths of this study is the topicality. Clarifying these relationships has important implications for workers' compensatory systems, too.

CONCLUSION

CTS is a multifactorial disease, a variety of risky factors (occupational, non-occupational) may significantly increase the risk of CTS development. Our results suggest that job duration, job rotation, repetitive movement, and hand-arm vibrations were factors significantly associated with CTS. The proper monitoring of employees' health is needed in order to determine the risky factors of CTS in working environment.

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Ethical Approval

The study protocol was approved by the Ethics Committee at the Jessenius Faculty of Medicine in Martin, Comenius University in Bratislava, Slovakia, reference number EK 138/2018, and was performed in accordance with the guidelines proposed in Declaration of Helsinki (2000) of the World Medical Association.

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