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COMPUTER USE AT WORK AND CARPAL TUNNEL SYNDROME: OVERVIEW OF SYSTEMATIC REVIEWS

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SUMMARY: There are many discussions regarding the impact of computer work, especially computer mouse use, in the development of carpal tunnel syndrome (CTS). The mechanism of such damage could be pressure or stretching of the median nerve in the carpal canal area. There is evidence that repetitive motion along with the use of force is a factor that contributes to the development of CTS, but computer work consists of mostly repetitive movements, without the use of force. Studies show that the prevalence of CTS in computer workers is similar to its prevalence in the general population. The general aim of this paper is to perform a literature search on the topic of whether there is a causal link between computer work and the development of CTS. The first specific goal is to try to quantitatively determine a relationship between exposure time and the development of symptoms, and the second specific goal is to try to set criteria, or guidelines, for the recognition of CTS as an occupational disease for those working on computers. A literature search on the databases ProQuest, PubMed, Google Scholar, and Cochrane Library. The key words used were: carpal tunnel syndrome AND computer work OR computer exposure OR keyboard use OR mouse use AND systematic review OR prospective cohort. The last search was performed on March 15, 2021. A total of 12 studies were included in this paper. The results were contradictory. Nine studies state that computer work does not pose an increased risk of CTS development. Two studies found that longer-term mouse use of more than 20 hours per week and keyboard use of more than 240,500,000 strokes per year may be associated with the development of CTS. One study showed people have a lower risk of developing CTSwhen working on a computer. We cannot determine with certainty the connection between computer work and the development of carpal tunnel syndrome. This calls into question the recognition of CTS as an occupational disease among those working on computers. Better planning and structured studies are needed to determine the intensity and duration of computer exposure and the level of damage to the median nerve, and then set criteria for the recognition of CTS as an occupational disease in these circumstances. Regardless of whether we recognize a particular disease as occupational, it is necessary to carry out preventive measures so that these health problems do not even occur, thereby keeping workers healthy and productive for as long as possible.

Key words: *computer work, carpal tunnel syndrome, occupational disease*

INTRODUCTION

Carpal tunnel syndrome (CTS) is a chronic compressive neuropathy, where the median nerve in the carpal tunnel, below the ligaments of the carpi transversum volare, is compressed *(Brinar et al., 2009)*. It is a repetitive strain injury (RSI) – an overuse injury caused by repeated microtraumas that overpower the ability of tissue to recover. The damage is of a chronic progressive course and in most cases the time of onset is unknown *(Pećina, 1992, Priručnik vježbe za prevenciju profesionalnih sindroma prenaprezanja gornjih ekstremi-*

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teta, 2016). It is usually idiopathic, and occurs in middle age, more often in women. Individual risk factors include adiposity (body mass index > 25), endocrine diseases (acromegaly, diabetes mellitus, hypothyroidism), rheumatoid and other arthritis of the wrist, trauma, and carpal tunnel edema in pregnancy *(Newington et al., 2015, Tomić, 2018, Burt et al., 2013)*.

Workplace risk factors that lead to the development of CTS are rapid repetitive movements of the wrist and fingers, pressure on the wrist, use of hand strength, distorted wrist position (dorsiflexion, ulnar deviation) and vibrations transmitted to the hands and arms *(Newington et al., 2015, Baričić et al., 2019)*. Repetitive movements of the hand and fingers lead to numerous tendon movements within the canal, microruptures in the subsynovial connective tissue, accumulation of fluid and, over time, the development of inelastic connective tissue. Fluid or connective tissue in a tightly framed canal puts pressure on structures, of which the median nerve is the most sensitive *(Bogadi-Šare, Zavalić, 2009)*. Simulations have shown that when a mouse is used, the median nerve elongates within the carpal tunnel by up to 8 mm, and repetitive finger motion while using the keyboard leads to nerve fatigue. These mechanisms could explain the development of CTS when individuals work with computer *(Mouzakis et al., 2014)*.

The clinical symptoms are pain and paresthesia that spread in the innervation area of the median nerve in the hand, and may extend to the forearm and upper arm. The first symptoms begin in the first three fingers (the palmar side of the thumb, forefinger and middle finger, and the radial side of the ring finger). They can be divided into three stages. In the first, mild but painful tingling and a feeling of swelling of the hand are present, mostly at night. The symptoms are reduced after shaking the fist (a sign of twitching) and changing the position of the wrist. In the second stage, difficulties are also present during the day, especially with repeated hand movements and prolonged maintenance of the hand in the same position. There is also clumsiness when working with hands and objects falling out of hands. In the third stage, the most severe, alongside the symptoms already present, hypotrophy or atrophy of the tenor muscles is visible. Abduction and thumb opposition are also difficult. Precise manual actions (unbuttoning buttons, closing jars) are difficult in this stage *(Brinar et al., 2009, Tomić, 2018, Baričić et al., 2019, MSD priručnik, 2014)*.

For the diagnosis of CTS, in addition to a well-performed anamnesis, clinical tests are also important to us. The Tinel test is most commonly used, and performed by percussion of the median nerve in the wrist in the area of the carpal tunnel, and is positive if paresthesias occur in the innervation area of the median nerve. Another test is the Phalen test, where the maximum flexion of the wrist is performed for 60 seconds, and it is positive if paresthesia and pain occur in the innervation area (*Baričić et al., 2019)*. Electromyoneurography (EMNG) is the gold standard in the diagnosis of CTS. Diagnostic criteria are prolonged motor and sensory latency of the median nerve, and slowed motor and sensory conduction velocity of the median nerve *(Baričić et al., 2019)*. The test is of high specificity (> 95%) and sensitivity (60-85%), and an aid for the exclusion of other pathological conditions in the differential diagnosis *(Newington et al., 2015, Tomić, 2018)*. Differential diagnostics should consider median nerve compression more proximal in the pronator tunnel near the elbow joint, C6 / C7 radiculopathy and polyneuropathy *(Newington et al., 2015)*. Treatment consists of ergonomic modifications (hand position between pronation and supination), analgesia, immobilization, and sometimes local steroid installation. In treatment-resistant patients, a surgical procedure is performed, which consists of cutting the transverse carpal ligament *(Brinar et al., 2009, Tomić, 2018, MSD priručnik, 2014)*.

In the general population, the prevalence in women is 3.0 to 5.8%, while in men it is 0.6 to 2.1% *(Andersen et al., 2003, Thomsen et al., 2008)*. The criteria used to define CTS play a significant role in determining prevalence. The literature shows that prevalence is much higher when only subjective problems are recorded than when clinical and neurophysiological criteria are used.

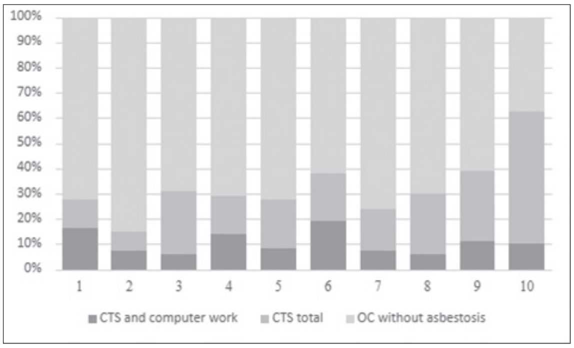
In a study from the Netherlands, the prevalence among women aged 25 to 74 in the general population was 9.2%. Approximately 5.8% of women had symptoms and positive findings on neurological testing but had not previously been diagnosed with CTS. The overall prevalence in men aged 25 to 74 years was significantly lower at 0.6% *(Giesiepen, Spallek, 2011)*. In one study on the population of southern Sweden, the prevalence for women aged 25 to 74 was 17.3%. Clinical examination of the same group showed a prevalence of only 4.6% and EMNG 5.2%. For men in southern Sweden, the prevalence of symptoms was 10.4%, after clinical examination 2.8%, and after EMNG 5.2% *(Giesiepen, Spallek, 2011)*. The annual incidence of CTS in Swedish and Italian studies is 428 to 506 cases per 100,000 for women and 139 to 189 cases per 100,000 men for men *(Kozak et al., 2015)*.

Computer work is defined by the EU Directive 90/270 / EEC (Directive on the minimum safety and health requirements for work with display screen equipment) and the Ordinance on the occupational safety of workers exposed to statodynamic, psychophysiological and other exertions at work as work where the worker, while performing work, uses a computer with a screen for a total of four or more hours during the working day.

Occupational diseases (OD) are those that are caused as a direct and exclusive consequence of exposure to hazards and conditions in the workplace *(Mustajbegović et al., 2018)*. They are defined through two criteria. First it is necessary to prove the presence of hazards and strain in work activities or the work environment. Secondly the intensity and the duration of exposure to the hazard/strain are at a level known and scientifically proved to damage health. It is also necessary to objectively determine the damage by a diagnostic method *(Šarić, Žuškin, 2002, Mustajbegović et al., 2018)*.

In order for any disease to be recognized as an OD in Croatia, it needs to be on the list of occupational diseases, which is of a closed nature and defined by the Law on the List of Occupational Diseases. Overuse syndromes are listed in Article 3, item 41 of that Act as those caused by cumulative trauma (repetitive movements, application of force, non-physiological position, vibrations and pressure), which includes CTS.

According to data from the Register of Occupational Diseases of the Republic of Croatia, kept in the Occupational Medicine Service of the Croatian Institute of Public Health, the number of carpal tunnel syndromes recognized as occupational diseases can be monitored *(Registar profesionalnih bolesti, 2021)*. In the last ten years, there have been 8 to 37 CTS recognized as OD per year. If we look at the distribution according to the National Classification of Activities – and in this paper are taken activities (Information and Communications, Financing, Real Estate, Public Administration, Administrative and Support Affairs) that use computers for most of the working time – the number of CTS ranges from 4 to 10. Graph 1 shows the share of the total number of CTS, that is, the share of CTS in computer work in occupational diseases. It can be seen that the share of CTS in OD is increasing, but on account off other risk factors (repetitive movements and vibrations), while the share of CTS as a result of working on a computer over a ten-year period is constant and around 10%. The average age of patients at the time of recognition of an OD is 53.92 years. The average duration of exposure at the time of diagnosis of an occupational disease is 22.8 years. From these data it is not apparent how many workers have applied for recognition of CTS as OD, nor how many have not been recognized and why.



Graph 1. The share of CTS in OD from year 1 (2010) to year 10 (2019)

Grafikon 1. Udio CTS-a u OD-u od 1. godine (2010.) do 10. godine (2019.)

In calculating the share of CTS in recognized OD, workers whose OD was recognized as a result of asbestos exposure are excluded, because they were mostly pensioners who initiated proceedings to exercise their rights under a special law *(Registar profesionalnih bolesti)*; (Table 1).

Table 1. Number of OD and CTS from the Register of Occupational Diseases in Croatia

Tablica 1. Broj OD-a i CTS-a iz Registra profesionalnih bolesti u Hrvatskoj

Year	OD all	OD without asbestosis	CTS all	CTS in J+K+L+O+N activities	Share of CTS in OD (%)	Average age*	Exposure time* *
2019	135	59	37	6	10.16	51.39	21.68
2018	137	80	31	9	11.25	51	24.84
2017	172	83	25	5	6.02	51.16	21.52
2016	153	55	13	4	7.27	48.85	23
2015	113	42	16	8	19.04	50.63	23
2014	168	62	17	5	8.06	49.41	23.41
2013	209	72	21	10	14.28	4843	22.48
2012	305	68	21	4	5.88	48.24	17.05
2011	448	53	8	4	7.54	49.5	26.75
2010	238	70	13	4	5.71	48.1	24.3

OD – occupational disease, according to the National Classification of Activities: J - *Information and Communications*; K – *Financing*; L - *Real Estate*; O - *Public Administration*; N - *Administrative and Support Affairs*

* average age when OD was diagnosed, in years

** average duration of working life at the time of diagnosis, in years

The highest number of OD was recorded in the group of workers with working experience of 21-30 years, which corresponds to the fact that a large proportion of OD require prolonged exposure, such as overuse syndromes, to develop. For carpal tunnel syndrome, the average is 20.5 years of working. This length of work exposure may also indicate that prevention measures in the workplace (technical and organizational measures) have failed. However, it could also demonstrate that health examinations as a measure of prevention have reached the maximum of their effectiveness, over a number of years of identical approach to prevention, and that they are not sufficient to prevent new cases of OD *(Registar profesionalnih bolesti, 2021)*.

The general goal was to investigate via the literature whether there is a cause-and-effect relationship between computer work and CTS development. The first specific goal was to try to quantify the relationship between exposure time and the development of symptoms, and the second specific goal was to try to set criteria or guidelines for recognition of CTS as an OD in computer work.

METHODS

Literature was searched on the following databases: ProQuest, PubMed, Google Scholar, and Cochrane Library. Keywords used were: carpal tunnel syndrome AND computer work OR computer exposure OR Keyboard use OR mouse use AND systematic review OR prospective cohort. Studies from 1995 until the last search on March 15, 2021 were included. During this period, studies related to computer work, CTS and EMNG diagnostics of this syndrome began to be published.

The selection criteria were:

- the included population used a computer in their workplace
- there was a carpal tunnel syndrome, diagnosed by electromyoneurography (EMNG, clinical examination)
- the relationship between exposure (duration of computer use, mouse use or keyboard use) and CTS is shown
- the study is prospective, a review paper or meta-analysis
- the study is in English.

A total of 837 studies were found. The first selection was made on the basis of title and abstract, excluding 785 papers. Duplicate studies, those that did not match the title, inappropriate studies, texts in books, and studies that had not been published in English or Croatian were excluded. The next selection was made after fully reading the papers. Studies were chosen that had the required population, defined exposures, diagnosed CTS, and in which data analysis was presented as Odds Ratio (OR) and 95% Confidence Interval (95% CI). Table 2 shows the characteristics of the included studies.

Table 2. Main characteristics of the included studies

Tablica 2. Glavne karakteristike uključenih studija

Author Year Country	Analysis	Number of studies included	Study design	Years included	Study population	Study aim
Kozak et al. 2015 USA	SR	10	5 SR 5 MA	1998-2014	Employed adults	To synthesize and critically evaluate the quality of SRs, and to assess the potential dose-response relationship
Mediouni et al. 2014 France	MA	6	4 CS 2 ChS	1992-2012	Employed adults	To undertake a systematic review and meta-analysis of the available epidemiological data regarding the association between computer work exposure and CTS
Shiri et al. 2014 Finland	MA	12	6 CS 3 CC 3 ChS	to 2014	6 studies with the general population, 6 among office workers	To assess whether computer use causes CTS by performing two separate meta-analyses on the comparison group – office workers and the general population
van Rijn et al. 2009 Netherlands	SR	44	30 CS 9 CC 5 ChS	1966-2007	Employed adults	To provide a quantitative assessment of the exposure-response relationship between work-related physical and psychosocial factors and the occurrence of CTS in occupational populations
Thomsen et al. 2008 Denmark	SR	8	4 ChS 3 CS 1 CC	-2008	A group exposed to computer work and a control group	To examine evidence for an association between computer work and CTS
Bhanderi et al. 2017 India	CC	1	CC		411 hospital patients at KM *Pater School of Physiotherapy*	To assess the association between CTS and computer use
Mediouni et al. 2015 France/USA	ChS	2	2 ChS		Cosali cohort – 3710 workers from France PrediCTS cohort – 1107 newly employed workers in USA	To explore the possible association between computer use and CTS using longitudinal data from two large cohorts, one from Europe and one from the USA
Eleftheriou et al. 2012 Greece	CS	1	CS	2012	461 Computer workers at a government data entry and processing unit	To investigate the association between keyboard use and CTS

Andersen et al. 2003 Denmark	ChS	1	1 year follow up	2000-2001	5658 technical assistants and machine technicians carrying out technical drawing tasks, administrative and graphical tasks	To determine the contribution of the weekly use of mouse devices and keyboards, work-related physical factors,work-related psychosocial factors, and individual characteristics in the occurrence and onset of possible CTS
Atroshi et al. 2007 Sweden	CS	1	CS	1997	2465 random general population sample of working age persons	To determine the frequency of keyboard use at work and the prevalence of CTS among randomly selected working-age people
Stevens et al. 2001 USA	CS	1	CS	1995	257 employees in the Mayo Clinic, identified as frequent computer users	To estimate the frequency of CTS in employees who use a computer
Hou et al. 2007 Taiwan	CS	1	CS	2007	340 male workers in an information and communication technology company	To survey the prevalence of CTS among of a group of male VDT workers

SR – *Systematic review*; MA – *Meta-analysis*; CS – *Cross sectional*; CC – *Case control*; ChS – *Cohort study*; CTS – *Carpal tunnel syndrome*

Figure 1. Flow chart of the selected studies
Slika 1. Dijagram toka odabranih studija

RESULTS

From four databases, 12 papers were selected that met the set criteria. Within these 12 papers, 86 primary studies were included. The studies are from different countries (the USA, France, Finland, Netherlands, Denmark, India, Greece, Sweden and Taiwan), and cover the period from 1995 to 2014. Three systematic review papers, two meta-analyses, four cross-sectional studies , two cohort studies and one case control study were included. The results of the included works are shown in Table 3.

Table 3. Main results of the included studies

Tablica 3. Glavni rezultati uključenih studija

Author	Exposure assessment	CTS assessment	Results OR (95%Cl)	Conclusion	Confounder
Kozak et al., 2015	SQ	CS EMNG	Computer: 1.7 (0.8-3.6) Keyboard: 1.1 (0.6-2.0) Mouse: 1.9 (0.9-4.2)	No evidence that occupational computer use can lead to relevant increases of CTS	BMI, age, sex, comorbidity
Mediouni et al., 2014	SQ	PE EMNG	Meta OR: Computer: 1.67 (0.79-3.55) Keyboard: 1.11 (0.62-1.98) Mouse: 1.94 (0.9-4.1)	It was not possible to show an association between computer work and CTS, although some particular work circumstances may be associated with CTS	/
Shiri et al., 2014	SQ	CS EMNG	General population - pooled 0.72 (0.58-0.90) > 1h in a day/ < 1h in a day 0.63 (0.38-1.04) > 4 h in a day/< 4 h in a day 0.68 (0.54-0.087) Office workers - pooled 1.34 (1.08-1.65) Frequent mouse use 1.84 (1.18-2.87) Frequent computer use 1.89 (1.15-3.09)	Suggested that excessive computer use, particularly mouse usage, might be a minor occupational risk factor for CTS	Only three studies take into account and other factors
van Rijn et al., 2009	SQ	CS+ PE or EMNG	Ali Computer work 8-12 / < 8 h/day 3.6 (1.3-10.3) >12 / < 8 h/day 4.4 (1.3-14.9) 4-8 / < 4 year 2.1 (1.3-3.6) >8 / < 4 year 2.7 (1.3-5.8) Hou Keyboard > 4 / < 4 h/day 1.34 (0.36-5.00) Mouse > 4 / < 4 h/day 0.85 (0.27-2.65)	In two studies, self-reported exposure to computer work > 8 h/day and mouse use for > 20 h/week were associated with CTS, with OR values of 3.6 and 2.6. In contrast, in five studies, no significant associations were found between CTS and the duration of keyboard use, the duration of mouse use, or frequency of mouse use (OR 0.9-3.4)	/
Thomsen et al., 2008	SQ	CS EMNG	Data not available	Evidence was insufficient to conclude that computer work (mouse and keyboard) causes CTS. As a consequence, this condition cannot be recognized as an occupational injury because of computer work	/

Bhanderi et al., 2017	SQ	PE + EMNG	Current use of computer 0.47 (0.27-0.94) Past use of computer 0.38 (0.11-1.35)	The study did not demonstrate any positive association between computer use and CTS	Education, obesity, short stature
Mediouni et al., 2015	Cosali – SQ (h/day) PrediCTS – job exposure matrix from O*NET	Cosali - PE PrediCTS – CS +EMNG	OR adjusted Computer work almost all day Cosali: 0.39 (0.17-0.89) PrediCTS: 0.16 (0.05-0.59)	Computer work was associated with lowered risk of CTS when compared to workers across multiple industries.	Age, sex, BMI, associated medical disorders, alcohol, tobacco
Eleftheriou et al., 2012	Calculated by payroll's registry: 1. Very low exposure < 101.400,000 ks/y 2. Low exposure: 101,400,001 – 208,000,000 ks/y 3. Medium exposure: 208,000,001 – 335,400,000 ks/y 4. High exposure: >335,400,000 ks/y	2 groups: A - personal history or surgery for CTS B – PE	Group A: > 240,500,000 ks/y 2.38 (1.38-4.12) Group B: > 149,500,000 ks/y 2.6 (1.8-3.73) Dose – response (OR) 4.HE 5.69 3.ME 4.0 2. LE 2.32 1. VLE 1.0	A possible association between cumulative exposure to keyboard strokes and the development of CTS after controlling for several confounding factors. A dose – response relationship between cumulative exposure to keystrokes and CTS was found	Age, BMI, smoking, physical activity, comorbidity
Andersen et al., 2003	SQ	PE	Mouse: 15-20 h/w 2.0 (0.9-4.2) Keyboard: 15-20 h/w 0.8 (0.4-1.5) > 20 h/w 1.4 (0.5-4.2)	The study emphasized that computer use does not pose a severe occupational hazard for developing symptoms of CTS	Age, sex, height, weight, leisure time activity, medical disorders
Atroshi et al., 2007	SQ	PE + EMNG	Keyboard use < 1 h /day 0.93(0.52-1.7) Keyboard use 1-4 h/day 0.55 (0.26-1.2) Keyboard use > 4 h /day 0.52 (0.23-1.2) Multivariate analysis (> 1 h/day / < 1 h/day): 0.51 (0.31-0.86)	Intensive keyboard use appears to be associated with lower risk of CTS	Age, sex, BMI, smoking
Stevens et al., 2001	SQ	PE EMNG	Keyboard: 0.9 (0.40-2.03) Mouse: 3.35 (0.76-15.76	The frequency of CTS in computer users is similar to that in the general population and suggests that using a computer in the setting studied does not enhance the risk of CTS	/
Hou et al., 2007	SQ	PE EMNG	Keyboard > 4 h/day 1.35 (0.36-5.05) Mouse > 4 h/day 0.85 (0.27-2.65)	The prevalence of CTS was 3.8%, and prolonged median motor distal latency was found in 3.7% of the subgroup. The results failed to demonstrate significantly higher risk of CTS among VDT workers	Age, BMI, smoking, exercise, medical history, job seniority

CTS – *Carpal tunnel syndrome*; CS – *Clinical symptoms*; PE – *Physical exam*; SQ – *Self-reported questionnaire*; EMNG – *Electromyoneurography*; ks/y – *Keyboard strokes per year*; BMI – *Body mass index*; O*NET – *Occupational network databas*

Information about exposure to computer work was mainly obtained through questionnaires whereby workers independently estimated time spent at the computer, or computer mouse or keyboard, in hours per day. In only one study was the estimate based on payroll records, where the workers' salary was keyboard stroke-dependent.

Carpal tunnel syndrome was confirmed in all studies by clinical examination and/or electromyoneurography.

Most studies took into account other factors that may influence the development of carpal tunnel syndrome (age, sex, BMI, comorbidities).

The results are contradictory. Nine studies state that working on a computer does not pose an increased risk for the development of CTS *(Kozak et al., 2015, Mediouni et al., 2014, Shiri, Kobra, 2015, Bhanderi et al., 2017, Thomsen et al., 2008, van Rijn et al., 2009, Mediouni et al., 2015, Stevens et al., 2001, Hou et al., 2007).* In two studies prolonged mouse use of more than 20 hours per week *(Andersen et al., 2003)* and keyboard use of more than 240,500,000 strokes per year *(Eleftheriou et al., 2012)* may be associated with the development of CTS. One study shows a *lower* risk of developing CTS when working on a computer *(Atroshi et al., 2007)*.

Two review papers, included in a meta-analysis by Kozak et al., who studied exclusively the connection between computer work and CTS development, found no evidence for a positive connection between computer work and CTS. The results of the meta-analysis also did not show an association between computer work and CTS (OR 1.7, 95% CI 0.8-3.6). There is also no statistically significant association if only the use of a keyboard or mouse is considered. Other studies included had insufficient or inconsistent results. They cite moderate quality of evidence regarding insufficient association between computer use and CTS development *(Kozak et al., 2015)*.

Mediouni et al. in their meta-analysis, failed to show a connection between computer work and CTS development. They noted that the results included were heterogeneous and sometimes contradictory due to different study designs, exposure estimates, and CTS definitions. Only one study found a positive association, but concluded that computer work does not pose a more serious risk of developing CTS . It is possible that the use a mouse along with poor ergonomic conditions may be associated with an increased risk of CTS, requiring adjustment of the workplace, but insufficient to diagnose occupational disease *(Mediouni et al., 2014)*

Shiri et al. *(2015)* in a meta-analysis analyzing the general population, found no dose-effect relationship between computer work and CTS. In a population of office workers, computer work defined as "frequent computer use" (OR 2.52 95% CI 1.25-5.11) and years of computer work (long vs. short) (OR 2.26 95% CI 1.57-3.25) were associated with CTS. In the same group, keyboard use and 'frequent keyboard use' were not associated with CTS *(Shiri, Kobra, 2015)*.

Van Rijn et al. came to contradictory results in their work. In two studies, with self-assessment of exposure, computer work longer than 8 hours per day (OR 3.6) and mouse use longer than 20 hours per week (OR 2.6) could possibly be associated with CTS. In five studies, there was no significant association between CTS and keyboard time or mouse time (OR 0.9-3.4). They also concluded that exposure assessment procedures were so different in studies that it was difficult to aggregate the dana *(van Rijn et al., 2009)*.

The study by Thomsen et al. *(2008)* states that working on a computer requires very little force. Experiments showed that the position of the fingers, wrists and forearms, comparable to the position common in computer use, led to an increase in intracarpal pressure, but not to levels that would be harmful. The average values of intracarpal pressure were 28-33 mmHg when the mouse was pulled or "clicked". Lower values were when the hand remained still on the mouse. Thomsen et al. *(2008)* conluded that there is insufficient evidence to conclude that computer work can lead to CTS, and therefore that diagnosis cannot be recognized as an occupational disease.

In their case control study, Bhanderi et al. *(2017)* analyzed patients who were treated in hospital (KM Pater School of Physiotherapy), and whose carpal tunnel syndromes were all proved by EMNG. The disadvantage was that the length of computer use was not defined; there was only a questionnaire on current ('has used the computer for at least 1 year') or previous ('has not used it for 6 months, but used it for at least 1 year') computer use. He concluded that his research confirmed that there is no connection between CTS and computer work *(Bhanderi et al., 2017)*.

Comparing the data of two cohorts in two different countries (France and the USA) over five years, Mediouni et al. *(2015)* came to the conclusion that there is no connection between computer work and new cases of CTS.

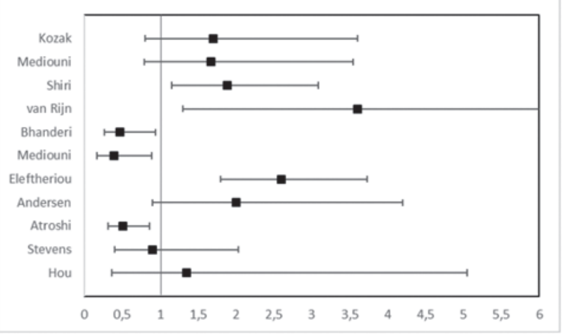
Eleftheriou et al. *(2012)* in their study monitored the relationship between the number of keystrokes per year and the development of CTS and managed to show that there is a dose-response relationship: that cumulative keyboard use is an independent predictor of CTS development. Multivariate regression analysis used for two groups of workers showed that workers with high cumulative exposure to keyboard shocks have an increased risk of developing CTS (Group A with operated or diagnosed CTS OR 2.23 (1.09-4.52), group B CTS confirmed by clinical examination OR 2.41 (1.36-4.25) *(Eleftheriou et al., 2012)*.

In a study by Andersen et al. a risk factor for the onset of CTS symptoms was the use of a computer mouse for more than 20 hours per week, with elevated OR values (20-25 h/week OR 2.6, 95% CI 1.2-5.5; 25-30 h/week OR 3.2, 95% CI1.3-7.9, > 30 h/week OR 2.7, 05% CI 1.0-7.6). When the keyboard and mouse were in use, the increased risk was when the mouse was used for more than 20 hours per week (OR 3.6, 95% CI 1.4-9.4). Based on the symptoms and the questionnaire, the prevalence of CTS was 1.4% - 4.8%, and the incidence of new or worsening symptoms was about 5.5%. When an electomioneurophysiological study was performed, the incidence dropped below 1%. The use of the keyboard is probably not related to the development of CTS, but they could not rule out a possible connection with more intensive work (> 12000 strokes per keyboard/h, 10 h/week, OR 1.8, 95% CI 1.1-3.2). The correct relationship between mouse use time and CTS symptoms could not be found *(Andersen et al., 2003)*.

The only study that showed a lower risk for the development of CTS when working on a computer was from Atroshi et al. *(2007)*. The general population was examined and the CTS was confirmed by clinical examination and EMNG testing. The prevalence of 2.6% in the group with intensive keyboard use (> 4 h/day) increased to 4.9% in the group with less workload (< 1 h/day), and the highest 5.2% in the group that did not use the keyboard at work. A possible reason would be that a group of respondents who reported using the keyboard for a short time were exposed to other repetitive movements that were not recorded. The reason for the protective effect of keyboard use could be that these are repetitive movements without the use of force, with a consequent reduction in the risk of developing edema and the associated increased intracranial pressure. They also note that people who use a computer are generally not exposed to other activities that increase the risk for CTS at their workplace *(Atroshi et al., 2007)*.

In the Stevens et al. *(2001)* study, the prevalence among the computer-using medical staff was similar to that of the general population, suggesting that computer work is not associated with an increased risk of developing CTS.

The same conclusion was reached by Hou et al. *(2007)*, where the prevalence of CTS of 3.8% among male computer workers (VDT) in Taiwan is similar to the general population.



Graph 2. OR and 95% CI. The black squares correspond to the OR, and the horizontal line to the 95% CI

Grafikon 2. OR i 95% CI. Crni kvadratići odgovaraju OR-u, a vodoravna linija 95% CI-ju

DISCUSSION

The results of this review confirm the results of most previous studies. By reviewing the literature it is not possible to come to a reliable conclusion about the connection between computer work and the occurrence of carpal tunnel syndrome, and accordingly it is not possible to set criteria for recognizing CTS as an occupational disease. Only two papers argued that longer-term mouse use, of more than 20 hours per week *(Andersen et al., 2003)* and keyboard use of more than 240,500,000 strokes per year *(Eleftheriou et al., 2012)*, may be associated with the development of CTS. One study even showed a reduced risk for the development of CTS when working on a computer *(Atroshi et al., 2007)*.

The methodology used to select articles and extract data could be a source of the limitations of this study. The Googlescholar database was used because previous studies had not searched that database, and no articles were found in the Cochrane Library (in contrast to other studies, which managed to find articles on that database). Then we have to take into account that there was an overlap of studies, meaning that the same primary studies were analyzed in several review papers, which could lead to misinterpretation of the findings. It would be necessary to determine the extent to which individual studies overlap in different review papers.

The source of difficulties in interpretation were different study results, different definitions of CTS and different evaluations of computer exposure time. For example, Shiri et al. *(2015)* found in her meta-analysis that frequent computer use by office workers may be associated with a higher risk of developing CTS (OR 2.52; 95% CI 1.25-5.11), especially mouse use, but the level of evidence was low. There was no association in the general population *(Shiri et al., 2015)*. In his cohort study, Andersen et al. (2003) linked mouse and keyboard use of more than 20 hours per week to the development of CTS (OR 3.6 (95% CI 1.4-9.4), while Atroshi et al. *(2007)* presented the protective effect of keyboard use in his cross-sectional study on a large population (OR 0.52 95% CI 0.23-1.2). Some of the studies defined CTS only by clinical symptoms or physical examination, without electromyoneurographic examination to objectify and confirm the change in the median nerve. This may have increased the number of number of CTS, which would have been lower by EMNG confirmation.

Studies made different definitions of computer work and evaluated computer exposure time differently. Various questionnaires were used in which workers independently assessed the length of exposure, that is, how long they used the computer during the working day. It is possible that workers tend to overestimate this time, especially if they have severe problems with the locomotor system. The studies measured the total time of computer use, without differentiating the time spent using the keyboard or computer mouse. Developing and using software that would objectively measure the total time spent using a computer, separating keyboard and mouse usage, would solve this problem *(Umker et al., 2007)*. The analysis did not take into account the organization of work, which can be performed at the worker's own rhythm. This form of work should be an advantage over regimented work, because it gives the worker the opportunity for more frequent breaks, and reduces the possibility of developing fatigue of the hand structures. Nowadays, when 74% of households own a personal computer and 81% have access to the internet *(Priopćenje Državnog zavoda za statistiku, 2019)*, we must distinguish between the time spent using a computer in leisure time and during work. The total time of exposure is higher, but measuring only the time spent using the computer at work, we could erroneously conclude that even with less exposure, the development of CTS symptoms will occur. The total exposure time in years should also be considered, because children start using computers and other gadgets early in life, as part of their education (online classes, assignments) and free time (social networks, games).

Although this study cannot with certainty link computer work with CTS, it is possible that several factors (hand position, palm pressure, poor posture, repetitive movements and job requirements), acting synergistically, may lead to the development of the symptoms of CTS, without the changes in EMNG required for the diagnosis of CTS. This phase also requires that occupational and sports medicine specialists act preventively. Primary and secondary prevention (prevention of disorders and early detection of symptoms) would include organizational measures together with interventions at the individual level. Occupational and sports medicine specialists should, in cooperation with employers, work on securing each worker a job to which they are ergonomically suited, taking into account different anthropometric characteristics, as well as body positions that will relieve the hands as much as possible. Another suggestion is short breaks that would be used for an active break, for example, a five-minute break every hour to perform stretching exercises. If it is possible work tasks should be rotated, for example alternating work on the computer with other work tasks. It is also important to engage in educating workers about working safely, and having a healthy lifestyle (proper diet, not smoking, getting enough sleep, methods of relaxation and inclusion in exercise programmes), and recognizing the early symptoms of CTS. Implementation of exercise programmes to prevent upper limb strain syndrome should include stretching exercises to develop and maintain flexibility, strength exercises to develop muscle endurance and exercises to develop motor control to ensure optimal mechanical efficiency with minimal load on tendon, cartilage and other structures. Kinesiologists should definitely be included in this *(Priručnik Vježbe za prevenciju profesionalnih sindroma prenaprezanja gornjih ekstremiteta, 2016)*.

The Ordinance on occupational safety of workers exposed to statodynamic, psychophysiological and other exertions at work determines the preventive examinations that employers must provide to their employees, and are focused on examining eyesight. These examinations should be extended to include the whole locomotor system.

It is necessary to develop a record system of symptoms and diseases related to work. Either through a special register, or as a part of the worker's health record, where the occupational medicine specialist could put notes related to the worker's symptoms, which are known to be work-related and which maybe do not meet the criteria for occupational disease. This should provide the worker certain benefits, such as more frequent use of annual leave, physical therapy, and inclusion in preventive exercise programmes. These measures could enable us to respond quickly when symptoms occur, prevent further development of symptoms, and thus keep the worker fit and efficient in their work.

CONCLUSION

This review showed that we cannot determine with certainty the connection between computer work and the development of carpal tunnel syndrome. This calls into question the recognition of CTS as an occupational disease of those working on a computer.

Better planned and structured, prospective, cohort studies need to be conducted to provide a quantitative assessment of the relationship between CTS and computer work. They should more precisely define the time spent working on a computer, distinguishing the exposure time on the keyboard and computer mouse, and include only EMNG-confirmed CTS. Individual factors as well as psychosocial and organizational requirements of the job should also be taken into account.

Thus we could determine the relationship between exposure and effect, and assess a safe level of exposure, in other words the level of exposure above which the development of CTS as an occupational disease is possible.

Whether we recognize a particular overuse syndrome as an occupational disease or not, computer workers develop certain symptoms; preventive measures need to be taken to stop them from occurring at all. These are organizational, technical, individual measures and extended health examinations, which require the joint efforts of workers, employers, occupational safety experts and occupational medicine and sports specialists, in order to keep workers healthy and productive.

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UPORABA RAČUNALA NA RADU I SINDROM KARPALNOG KANALA: OSVRT NA SUSTAVNE STUDIJE

SAŽETAK: Mnoge rasprave bave se utjecajem rada na računalu, napose rada s mišem, u nastajanju sindroma karpalnog kanala. Mehanizam oštećenja mogao bi se pripisati pritisku ili istezanju medijalnog živca u području karpalnog kanala. Postoje dokazi da ponavljajuće radnje i uporaba sile čine faktor koji pridonosi nastanku sindroma karpalnog kanala, no rad na računalu koji se većinom sastoji od ponavljajućih radnji ne zahtijeva uporabu sile. Studije pokazuju da je učestalost ovog sindroma kod osoba koje rade na računalu slična onoj u općoj populaciji. Glavni cilj rada je istražiti literaturu povezanu s ovaim problemom, tj. utvrditi postoji li uzročna veza između rada na računalu i nastanka sindroma karpalnog kanala. Prvi cilj je kvantitativno utvrditi odnos vremenske izloženosti i pojavu simptoma, a drugi cilj je utvrditi skupinu kriterija ili uputa za priznavanje sindroma karpalnog kanala kao profesionalne bolesti u osoba koje rade na računalima. Pretraga literature temeljena je na bazama podataka ProQuest, PubMed, Google Scholar i Cochrane Library. Korištene su sljedeće ključne riječi: sindrom karpalnog kanala I rad na računalu ILI izloženost računalu ILI uporaba računala ILI uporaba miša I sustavni pregled ILI prospektivna kohortna studija. Posljednja pretraga izvršena je 15. ožujka 2021. Ukupno je istraženo 12 studija. Rezultati su bili kontradiktorni. Devet studija navelo je da rad na računalu ne predstavlja povećani rizik nastanka sindroma karpalnog kanala. Dvije studije utvrdile su da dugotrajna uporaba miša, dulja od 20 sati tjedno, i rad na tipkovnici veći od 240.500.000 udaraca godišnje mogu biti povezani s nastankom sindroma karpalnog kanala. Jedna je pak studija utvrdila da osobe koje rade na računalu imaju manji rizik nastanka sindroma. Dakle, ne može se sa sigurnošću tvrditi da postoji veza između rada na računalu i nastanka sindroma karpalnog kanala. Upitno je stoga može li se sindrom priznati kao profesionalna bolest osobama koje rade na računalu. Potrebno je bolje planirati i bolje strukturirati studije za utvrđivanje intenziteta i trajanja izloženosti računalu i razine oštećenja medijalnog živca kako bi se mogli utvrditi kriteriji za priznavanje sindroma kao profesionalne bolesti. Bez obzira može li se određena bolest priznati kao profesionalna ili ne, potrebno je uvesti preventivne mjere kojima bi se izbjegla pojava zdravstvenih teškoća a sve kako bi djelatnici ostali zdravi i produktivni koliko god je moguće dulje.

Ključne riječi: *rad na računalu, sindrom karpalnog kanala, profesionalna bolest*

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