Occupational Medicine, 2024, **XX**, 1–7
https://doi.org/10.1093/occmed/kqae120
Advance access publication 22 November 2024

OXFORD

Carpal tunnel syndrome severity and work: a case-control study

S. Curti[1], F. Ginanneschi[2], C. Salce[3], A. Argentino[4], S. Mattioli[5], M. Mondelli[6]

[1]Department of Medical and Surgical Sciences, University of Bologna, Bologna 40138, Italy
[2]Department of Medical, Surgical and Neurological Sciences, University of Siena, Siena 53100, Italy
[3]Consultant Occupational Physician, Bologna 40100, Italy
[4]Department of Public Health, Local Health Unit 'Romagna', Ravenna 48121, Italy
[5]Department of Environmental and Prevention Sciences, University of Ferrara, Ferrara 44121, Italy
[6]EMG Service, Local Health Unit Toscana Sud Est, Siena 53100, Italy

Correspondence to: S. Mattioli, Department of Environmental and Prevention Sciences, University of Ferrara, via Fossato di Mortara 64/b, 44121 Ferrara, Italy. Tel: +39 0532 455 565; e-mail: stefano.mattioli@unife.it

Background: Carpal tunnel syndrome (CTS) is a socially relevant condition. Risk factors associated with CTS severity and work have not been explored.

Aims: This case-control study aims to investigate the association between CTS severity and occupational biomechanical overload considering personal anthropometric risk factors.

Methods: We consecutively enrolled one CTS case for two controls. CTS cases were grouped into three classes of progressive clinical and electrophysiological severity according to two validated scales. Job titles were coded according to the International Standard Classification of Occupations (ISCO 88) and grouped into two broad socio-occupational categories: blue-collar and white-collar workers.

The associations between CTS (or CTS severity) and blue-collar status were assessed using unconditional (or multinomial) logistic regression models adjusted for age, gender, centre and two anthropometric indexes: wrist-palm ratio and waist-stature ratio. Odds ratios (OR) or relative risk ratio and 95% confidence intervals (95% CI) were calculated, as appropriate.

Results: We included 183 cases and 445 controls. Blue-collar status was a risk factor for CTS (OR 2.4; 95% CI 1.5–3.8). Among job titles, vine and/or olive tree growers (OR 6.0; 95% CI 2.0–17.9) and food processing workers (OR 4.8; 95% CI 1.5–15.2) were at higher risk. At multinomial logistic regression analysis, blue-collar status and the two anthropometric indexes were associated with moderate/severe CTS, after mutual adjustment.

Conclusions: Blue-collar workers showed a higher risk of CTS than white-collar workers, adjusting for anthropometric and body measures as well. Preventive interventions should be addressed to decrease the biomechanical overload of the upper limbs and limit the overweight.

INTRODUCTION

Carpal tunnel syndrome (CTS) is the most frequent focal peripheral neuropathy in the general population [1,2], especially among manual workers [3–5]. CTS causes hand disability, high costs of health care and loss of workdays [6]. Several risk factors for CTS have been studied including personal/anthropometric factors, co-morbidities, psychosocial and occupational risk factors [7–11]. Epidemiological studies showed an association between CTS and exposure to biomechanical overload, which is more common among manual than non-manual workers [11–14]. Two prospective multicentre studies carried out in Italy and USA provided information about the association between CTS incidence and exposure to forceful exertion, peak of hand force, forceful repetition and hand-arm vibrations [13–15]. More recently, another cohort study based on exposure measurement reported an association between high wrist angular velocity and CTS [16]. In addition, personal and biomechanical risk factors along with psychosocial job factors were found to predict CTS-related disability [7].

We reported a case-control study on CTS and several body/hand anthropometric measurements showing an association between many anthropometric indexes and CTS severity [17]. Among body and hand measures, the waist–stature ratio (WSR) and wrist–palm ratio (WPR) showed the strongest association with the onset and severity of CTS [18,19]. However, little is known about the association between occupational risk factors and CTS severity [20–23].

The aim of this case-control study is to investigate the association between CTS (and CTS severity) and occupational biomechanical overload considering body and hand anthropometric measures as potential confounders.

Key learning points

What is already known about this subject:

- Several risk factors for carpal tunnel syndrome (CTS) have been investigated; however, the association between CTS severity and work has not been explored.

What this study adds:

- This case-control study investigated the association between CTS severity and occupational biomechanical overload adjusting for body and hand anthropometric measures.
- An association between moderate/severe forms of CTS and occupational biomechanical overload was found.

What impact this may have on practice or policy:

- Identifying risk factors for CTS severity is important to develop preventive strategies.
- Effective preventive interventions should be targeted to decrease the biomechanical overload of the upper limbs and limit overweight.

METHODS

For the purpose of the present study, we reviewed the data collected in a previous case-control study [24]. We enrolled one case for two controls regardless of age, gender and occupation among all patients referred to three outpatient electromyography laboratories (EMG labs), who performed electrodiagnostic testing for the first time because of upper limb complaints. The diagnosis of CTS was made according to clinical and electrophysiological findings [25]. The inclusion criteria for CTS were those recommended by the American Academy of Neurology [26]. All hands with the clinical diagnosis of CTS were included in the 'classic/probable' or 'possible' categories according to the modified hand diagram [25]. Controls were selected among all the other patients admitted in the same period to the same EMG labs with upper limb symptoms other than CTS and normal neurography of the median nerve.

We excluded all patients with diabetes, connective and thyroid diseases, renal failure, gout, polyneuropathy, amyotrophic lateral sclerosis, onset of symptoms during pregnancy or lactation, history of alcoholism, wrist and hand trauma, upper limb surgery, malignancy in the previous 5 years, and previous intake of medication considered toxic to the peripheral nervous system.

Current occupational activity was recorded in two out of three EMG labs participating in the original study. These data were reviewed for the present analysis. Specifically, three occupational physicians (C.S., A.A. and S.M.), blinded to case/control status, independently evaluated the descriptions of the occupational activities reported in the medical records, and classified them according to the International Standard Classification of Occupations (ISCO 88) [27]. An occupational physician (S.M.), blinded to case/control status, grouped these subjects based on the amount of occupational biomechanical overload in two broad socio-occupational categories: blue-collar workers and white-collar workers [28]. Considering that the amount of biomechanical overload experienced by Italian housewives is partially comparable to that experienced by specific blue-collar jobs (like domestic cleaners) [29], we decided to include them in the blue-collar category. As previously reported, the typical housework tasks encountered by Italian housewives were characterized by repetitive/similar movements (for >2 h/day) along with ≥30° bending of the wrists, ≥45° stretched wrists, ≥30° ulnar stretches and manual force [29]. The study was approved by the local ethics committee of the Local Health Unit 'Toscana Sud-Est' and of the University Hospital of Siena on 4 October 2010 (code STC-MANO-2010).

Electrophysiological methods included the study of motor and sensory conduction velocities (SCV) of the median and ulnar nerves and the differences between the two nerves in SCV of the fourth digit-wrist segment and in distal motor latencies (DML). In case only one of the aforementioned electrodiagnostic tests was abnormal, we measured the difference between the latencies of the median and ulnar nerves in the 8 cm palm-to-wrist segment, the differences between the median and radial nerves in SCV of the first digit-wrist segment, and the difference between DML recorded from the second lumbrical–second interosseous muscles [24]. If at least one absolute and one comparative electrodiagnostic test, or two comparative tests of the median nerve were abnormal, a patient with CTS symptoms was included among the cases. Patients who had symptoms suggestive of CTS but normal electrodiagnostic testing were excluded along with those patients with asymptomatic delay in distal conduction velocity of the median nerve.

During the electrodiagnostic study, the following anthropometric measurements were taken: height, weight, waist and hip circumferences, width and depth of the wrist, length of the palm, of the third digit and of the hand and width of the palm. Derived ratios were calculated as well.

The inter-examiner agreement for all body and hand measurements was measured in 17 volunteers as previously reported elsewhere [24].

If bilateral symptoms were present, the hand with the most severe symptoms was measured or, if there were no differences between sides, the dominant hand was selected.

Using a validated five-stage scale, we evaluated the clinical severity of CTS by assessing the timing of any type of paraesthesia that occurred within the last 2 weeks, the objective sensory deficits, the thumb opposition and abduction strength, and the status of the thenar eminence muscles [30] (Table 1). Moreover, we assessed the electrophysiological severity of CTS using a validated five-stage scale [31]. This evaluation involves the presence or absence of motor and sensory response, normal or abnormal SCV, DML of the median nerve and comparative nerve conduction velocity testing (Table 1).

Descriptive statistics were presented as mean and SD or number and percentage, as appropriate. The main analysis was focussed on the active working population (i.e. ≤65 years old). Subjects without any data on occupational activities, retired subjects, subjects older than 65 years old and unemployed subjects were excluded from the main analysis. As mentioned before, subjects were grouped into two broad socio-occupational categories based on occupational biomechanical overload, namely white-collar and blue-collar workers (including housewives) [28,29]. Considering that body and hand variables, as

Table 1. Clinical and electrophysiological severity scales for CTS

Stage	Three-level classification	Description
Clinical severity scale [30]		
I	Mild	Paraesthesia only at night and/or on waking in any part of the hand innervated by the median nerve
II	Mild	Paraesthesia during the day even in case of transient diurnal symptoms after repetitive movements or prolonged postures
III	Moderate	Any degree of sensory deficit in any region of the hand supplied by the median nerve
IV	Severe	Hypotrophy and/or motor weakness of the median-supplied thenar muscles
V	Severe	Atrophy and/or plegia of the same muscles
Electrophysiological severity scale [31]		
I	Mild	Normal digit-wrist segment (M3 and M4 SCV) and abnormal comparative median/ulnar or median/radial nerves neurographic tests
II	Mild	Slowing of median digit-wrist segment SCV and normal DML
III	Moderate	Slowing of digit-wrist segment SCV and DML delay
IV	Severe	Absence of SNAP in digit-wrist segment (at least M4) and DML delay
V	Severe	Absence of SNAP and CMAP

CMAP, compound muscle action potentials; M3, third digit-wrist segment of the median nerve; M4, fourth digit-wrist segment of the median nerve and SNAP, sensory nerve action potential.

well as their derived ratios, are often co-related to each other and might cause multiple collinearities in multivariable analysis, we chose to include in our analyses two indexes: (i) WPR (i.e. wrist depth/palm length), which refers to hand dimensions and (ii) WSR (i.e. waist circumference/height), which is a measure of the body size. These two indexes reported the highest sensitivity and specificity in discriminating subjects with CTS from those without CTS, while their accuracy tended to increase with CTS severity [18,19]. Considering the differences by gender in hand and body measurements, WPR and WSR were included as binary variables using predefined cut-off values: (i) WPR: 0.385 for women and 0.397 for men and (ii) WSR: 0.540 for women and 0.569 for men [18].

At first, we fitted univariate and multivariable unconditional logistic regression models to study the association between selected personal factors and the risk of CTS. Multivariable analysis included socio-occupational status (i.e. blue-collar and white-collar workers), WPR category and WSR category as well as age group (coded in three categories, ≤45, 46-55, 56–65 years), gender and enrolment centre. In addition, to evaluate the risk associated with job titles a multivariable unconditional logistic regression model was fitted controlling for age group, gender, enrolment centre, WPR category and WSR category. White-collar workers were taken as the reference category. We estimated odds ratios (OR) and 95% confidence interval (95% CI) according to Breslow and Day [32].

Due to limited sample size, we grouped both clinical and electrophysiological severity scale of CTS into two-level classification: (i) mild CTS (Stages I or II) and (ii) moderate/severe CTS (Stages III or IV or V) and three-level classification: (i) mild CTS (Stages I or II); (ii) moderate CTS (Stage III) and (iii) severe CTS (Stages IV or V) (Table 1). We then fitted multinomial logistic regression models to study the association between clinical and electrophysiological severity of CTS and broad socio-occupational categories. We estimated relative risk ratios (RRRs) and 95% CI considering people without CTS as the base outcome. All analyses were performed using STATA 17 software package. An alpha error of 0.05 was accepted.

RESULTS

The original database included 1117 patients: 370 cases (68% women) and 747 controls (64% women). All patients were Caucasians. After the exclusion of (i) subjects without detailed information on occupational history (mainly outpatients from one of the three EMG labs included in the study), (ii) retired and unemployed subjects and (iii) subjects older than 65 years old, we included in the main analysis 183 cases (46.4 ± 9.3 years; 132 women and 51 men) and 445 controls (43.2 ± 10.9 years; 276 women and 169 men).

Table 2 reports univariate and multivariable analysis of socio-occupational categories and individual factors. At multivariable unconditional logistic regression analysis, risk factors were blue-collar status (OR 2.4; 95% CI 1.5–3.8), WPR ≥ cut-off (OR 3.3; 95% CI 2.2–4.9) and WSR ≥ cut-off (OR 1.6; 95% CI 1.1–2.4). At gender stratification (Table 1, available as Supplementary data at *Occupational Medicine* online), blue-collar status and WPR ≥ cut-off turned out to be stronger risk factors for men (OR 4.2; 95% CI 1.5–12.0 and OR 4.6; 95% CI 2.2–9.9, respectively) than for women (OR 1.9; 95% CI 1.2–3.3 and OR 2.8; 95% CI 1.7–4.5, respectively).

Table 3 reports the analysis by job titles. Raised ORs were observed for vine and/or olive growers (OR 6.1; 95% CI 2.0–18.1), food processing workers (OR 4.9; 95% CI 1.5–15.4), cleaners and domestic helpers (OR 3.9; 95% CI 1.7–9.0), drivers and mobile plant operators (OR 3.1, 95% CI 1.2–8.1) and metal workers (OR 2.7, 95% CI 1.0–7.0).

Table 4 shows the distribution of white- and blue-collar workers according to the five-stage scale for clinical and electrophysiological severity of CTS [30,31]. The proportion of white-collar workers classified as having severe CTS was lower than among blue-collar workers. Out of 193 white-collar

Table 2. Risk factors for CTS in terms of socio-occupational categories and personal anthropometric factors

	Cases *N* = 183	Controls *N* = 445	Univariate[a] OR (95% CI)	Multivariable[b] OR (95% CI)
Occupational categories				
White-collars	31	162	1.0	1.0
Blue-collars	152	283	2.8 (1.8–4.4)	2.4 (1.5–3.8)
WPR categories				
<Cut-off[c]	74	297	1.0	1.0
≥Cut-off	109	148	3.7 (2.5–5.5)	3.3 (2.2–4.9)
WSR categories				
<Cut-off[d]	100	315	1.0	1.0
≥Cut-off	83	130	2.1 (1.5–3.1)	1.6 (1.1–2.4)

[a]Unconditional logistic model adjusted for age group, gender and enrolment centre.
[b]Unconditional logistic model adjusted for age group, gender, enrolment centre, white-/blue-collar status, WPR category and WSR category.
[c]WPR predefined cut-off: 0.385 for females and 0.397 for males [18].
[d]WSR predefined cut-off: 0.540 for females and 0.569 for males [18].

Table 3. Job titles and risk of CTS

Job-titles	ISCO codes	Cases *N* = 183	Controls *N* = 445	Univariate[a] OR (95% CI)	Multivariable[b] OR (95% CI)
White-collar workers	1, 21, 22 (not 2230), 23, 24, 311, 312, 315, 341, 346, 3471, 41 (not 4142), 42 (not 4211), 516	31	162	1.0	1.0
Tree (mainly vine and/or olive) growers and horticulturists	6112, 6141	12	7	12.7 (3.9–41.5)	6.1 (2.0–18.1)
Food processing workers	741, 827	7	9	6.2 (1.9–19.8)	4.9 (1.5–15.4)
Cleaners and domestic helpers	913	18	16	4.3 (1.8–9.9)	3.9 (1.7–9.0)
Miscellaneous service workers	3475, 4142, 4211, 5141, 5220, 9111, 9141, 9142, 9162	16	25	3.3 (1.5–7.3)	3.0 (1.4–6.7)
Drivers and mobile plant operators	3415, 832, 833	9	22	3.9 (1.4–11.0)	3.1 (1.2–8.1)
Leather, shoes and textile workers	7433, 7437, 7441, 826	7	8	4.4 (1.4–14.1)	3.0 (0.9–9.4)
Crops and animal producers	6111, 6121, 6122, 6130, 9211	8	9	4.7 (1.5–14.8)	2.8 (0.9–8.5)
Metal workers	7212, 7221, 7223, 7231, 7233, 8211, 8212, 8281	10	18	4.5 (1.6–12.3)	2.7 (1.0–7.0)
Nurses and paramedical workers	2230, 3226, 5132, 5133	9	18	2.4 (1.0–6.0)	2.2 (0.9–5.7)
Miscellaneous blue-collar workers	7111, 7113, 7122, 713, 7142, 724, 7313, 732, 7422, 8131, 8139, 8143, 8159, 8221, 8240, 828, 9151, 9312, 9322, 9333	26	89	1.8 (1.0–3.4)	1.5 (0.8–2.9)
Housewives	5121	20	36	1.8 (0.8–3.7)	1.9 (0.9–3.9)
Cooks and bartenders	5122, 5123	10	26	1.8 (0.8–4.3)	1.7 (0.7–4.1)

[a]Unconditional logistic model adjusted for age group, gender and enrolment centre.
[b]Unconditional logistic model adjusted for age group, gender, enrolment centre, job-title categories, WPR category and WSR category.

workers, two were classified with severe CTS according to the clinical severity scale, while one was classified as such according to the electrophysiological severity scale of CTS. Conversely, out of 435, blue-collar workers with severe CTS were 13 (3%) for the clinical severity scale and 19 (4%) for the electrophysiological severity scale. Of note, housewives (n = 57 female subjects, 9% of all the study population) had the highest proportion of severe CTS in the clinical and electrophysiological severity scales (27% and 30% of all the severe cases of CTS, respectively).

Table 5 presents the RRRs estimated through multinomial logistic regression models according to clinical and electrophysiological severity scale (two-level classification). Blue-collar

Table 4. Distribution of white- and blue-collar workers among different stages of clinical and electrophysiological severity scales of CTS

Stage	Three-level classification	Two-level classification	Clinical severity scale [30]		Electrophysiological severity scale [31]	
			White-collar workers N = 193 n (%)	Blue-collar workers N = 435 n (%)	White-collar workers N = 193 n (%)	Blue-collar workers N = 435 n (%)
0	Absence of CTS	Absence of CTS	162 (84)	283 (65)	162 (84)	283 (65)
I	Mild CTS	Mild CTS	10 (5)	34 (8)	7 (4)	25 (6)
II			8 (4)	53 (12)	5 (3)	25 (6)
III	Moderate CTS	Moderate/Severe CTS	11 (6)	52 (12)	18 (9)	83 (19)
IV	Severe CTS		1 (1)	11 (3)	0 (0)	17 (4)
V			1 (1)	2 (1)	1 (1)	2 (1)

Stage '0' corresponds to control subjects.
Percentages do not total 100, due to rounding.

Table 5. Risk factors for CTS severity

	Clinical severity scale (Two-level classification)[a] [30]		Electrophysiological severity scale (Two-level classification)[a] [31]	
	Mild CTS N = 105	Moderate/severe CTS N = 78	Mild CTS N = 62	Moderate/severe CTS N = 121
	RRR (95% CI)	RRR (95% CI)	RRR (95% CI)	RRR (95% CI)
Blue-collar workers	2.5 (1.4–4.4)	2.0 (1.0–4.0)	2.3 (1.2–4.6)	2.4 (1.4–4.2)
[b]WPR ≥ cut-off	2.3 (1.4–3.7)	5.4 (3.0–9.7)	2.4 (1.4–4.3)	4.1 (2.5–6.6)
[c]WSR ≥ cut-off	1.2 (0.7–2.0)	2.4 (1.4–4.0)	1.2 (0.7–2.1)	1.9 (1.2–3.1)

[a]Multinomial polytomous logistic regression models adjusted for gender, age group, enrolment centre, white-/blue-collar workers, WPR category, WSR category; control subjects as base outcome.
[b]WPR predefined cut-off: 0.385 for females and 0.397 for males [18].
[c]WSR predefined cut-off: 0.540 for females and 0.569 for males [18].

status and the two anthropometric indexes were associated with mild and moderate/severe forms of CTS, after mutual adjustment. The multinomial logistic regression models performed according to the three-level classification of clinical and electrophysiological severity scale (Table 2, available as Supplementary data at *Occupational Medicine* online) showed that WPR category was a risk factor also for the more severe forms of CTS with the strength of association increasing across clinical and electrophysiological severity strata.

DISCUSSION

This study investigated the association between occupational category and clinical and electrophysiological severity scale of CTS. Our findings confirm the association between blue-collar status and CTS [28,33]: the risk was doubled for this occupational category with respect to white-collar workers.

Blue-collar work, overweight and narrow carpal tunnel are independent risk factors that can potentiate each other: the point estimate for overweight blue-collar workers with narrow carpal tunnel in comparison to slim/normal-weight white-collar workers with large carpal tunnel is an OR of 16.9 (95% CI 7.4–38.8) (data not shown).

Blue-collar workers are exposed more frequently than white-collar workers to manual work and to biomechanical overload of the upper arm [28,33]. Blue-collar work can determine exposure to repetitive and forceful movements of hand and wrist, powerful grip, non-neutral posture of the wrist, palmar compression and hand-arm vibration [11,16]. The increased tension of the flexor tendons of the fingers, the contraction of the lumbrical muscles and the incursion of the muscles 'flexor digitorum superficialis and profundus' into the carpal tunnel during forceful movements of hand able to increase the carpal tunnel pressure, especially in short and wide hands and in squared wrists that match with deep and narrow carpal canal [34]. The analysis by job title confirmed that many occupational activities could be considered at risk for CTS, including not only assembly-line duties, commonly represented in industrial settings, but also tasks encountered in agriculture and in service sector [28]. Of note, in the Province of Siena, many farmers are vine and/or olive growers. In this specific case, pruning and harvesting exposed them to repetitive and forceful movements of hand and wrist, powerful grip, non-neutral posture of the wrist and palmar compression. This could explain the 6-fold increased risk of CTS (Table 3). Of note, in a recent descriptive study on CTS diagnosed with clinical and electrodiagnostic findings, it has been shown that CTS was more severe among landscapers, textile workers, musicians and among those who carry out household tasks [22]. In the present study, the high proportion of moderate/severe cases among housewives (12 out 56 and 15 out 56 in clinical and electrophysiological severity scale, respectively) supports the hypothesis that biomechanical loads experienced during housework should be considered (not only among housewives) while analysing data from epidemiological studies on CTS aetiology [29].

An incidence study based on hospital discharge records of surgically treated cases of CTS reported a 4-fold higher rate for blue-collar workers in comparison to white-collar workers [3]. More recently, another study based on surgically-treated cases of CTS showed a 3-fold risk for farmers and manual workers as compared to clerical workers [5]. In addition, a case-control study reported a 7-fold risk of operated CTS among blue-collar workers, after adjusting for non-occupational risk factors [28]. Patients who undergo surgical treatment for CTS are usually those who have a more severe clinical and electrophysiological profile [35]. Consequently, these findings may support a higher risk for severe CTS with respect to mild or moderate CTS for blue-collar workers in the electrophysiological severity scale. However, in the stratum of severe CTS, the number of patients was too small to reach the statistical power needed to detect a meaningful difference (Table 4 and Table 2, available as Supplementary data at *Occupational Medicine* online). Previously, two studies (one based on EMGs and another based on symptoms) were in favour of a higher risk of severe CTS among blue-collar workers [20,21], but a third study did not support it [23]. With respect to other risk factors, the study by Ghasemi *et al.* did not find an association of overweight or wrist measurements with more severe CTS among blue-collar workers; on the other hand, Tonga *et al.* reported an association with BMI [20,23]. In our multivariable analysis, high WSR (i.e. larger waist circumference as compared to stature) was a relevant risk factor for moderate and severe CTS, while high values of WPR (i.e. 'stubby hands', squared wrist with short and wide hand) increased the risk of all the stages of CTS severity, in particular moderate and severe CTS categories.

The main strengths of the present study are the thorough assessment of anthropometric characteristics as well as the rigorous protocol for the diagnosis of CTS. In particular, the anthropometric measurement was based on standardized and reproducible methods [24]. For this study, we selected two ratios: one of the body sizes and one of the hand configurations that had the highest sensitivity and specificity to identify subjects with CTS [18]. We used a rigorous diagnostic protocol for the identification of CTS cases based on restrictive selection criteria, since it included the coexistence of symptoms and neurographic abnormalities. We enrolled CTS patients with clinical symptoms and two electrophysiological abnormalities, considering that one abnormality on electrophysiological testing could be due to chance. Subjects with CTS symptoms and normal electrodiagnostic tests and subjects with asymptomatic delay of distal conduction velocity of the median nerve were excluded from the study. Therefore, our inclusion criteria reduced the number of false positive cases. The analyses were adjusted for age and gender, considering that age is related to the severity of CTS and anthropometric measures are different in men and women. Other potential confounding factors related to medical history did not affect our findings because cases and controls with co-morbidities were excluded *a priori* from the enrolment.

Our study has also some limitations that need to be considered. First of all, the small amount of CTS cases in the IV and V stages of the clinical and electrophysiological severity scales limited the statistical power regarding the association between risk factors and severe CTS.

Even if our EMG labs admitted only unselected and unsolicited patients, our cohort might differ from the general population. In particular, control subjects were enrolled among the patients admitted to the same EMG labs as cases because of upper limb complaints other than CTS. More than 70% of them had no diseases of the peripheral nervous system and considering that diseases/disorders of hand, elbow, neck and shoulder may potentially be more frequent among blue-collar workers, our results could be underestimated [36]. Furthermore, we did not assess the individual level of biomechanical exposure, but we used the job titles to classify workers as blue- or white-collars, hence with higher or lower occupational biomechanical load. In addition, we did not evaluate the exposure to non-occupational biomechanical overload including leisure time activities as well as domestic chores. This should be taken into account in further studies. In conclusion, we found that blue-collar workers were more at risk of CTS with respect to white-collar workers, adjusting for anthropometric and body measures as well. Our results support an association between moderate/severe forms of CTS and occupational biomechanical overload.

Blue-collar work and anthropometric measures (of body and hand/wrist) are independent risk factors that can potentiate each other in generating not only CTS cases [5], but also moderate/severe cases of CTS. Although it is not possible to modify hand/wrist anthropometric measures, preventive interventions should be addressed to decrease the biomechanical overload of the upper limbs and limit overweight.

Further studies with a large number of severe cases of CTS will contribute to provide conclusive evidence on the relationship between occupational biomechanical overload and CTS severity.

ACKNOWLEDGEMENT

Our thanks to Alessandro Aretini (neurophysiological technician of EMG Lab, ASL Toscana Sud Est) for his valuable help in EMG data collection.

FUNDING

None declared.

COMPETING INTERESTS

None declared.

REFERENCES

1. Mattioli S, Baldasseroni A, Curti S *et al.* Incidence rates of in-hospital carpal tunnel syndrome in the general population and possible associations with marital status. *BMC Public Health* 2008;**8**:374.
2. Mondelli M, Giannini F, Giacchi M. Carpal tunnel syndrome incidence in a general population. *Neurology* 2002;**58**:289–294.
3. Mattioli S, Baldasseroni A, Curti S *et al.* Incidence rates of surgically treated idiopathic carpal tunnel syndrome in blue- and white-collar workers and housewives in Tuscany, Italy. *Occup Environ Med* 2009;**66**:299–304.
4. Dale AM, Harris-Adamson C, Rempel D *et al.* Prevalence and incidence of carpal tunnel syndrome in US working populations: pooled

analysis of six prospective studies. *Scand J Work Environ Health* 2013;**39**:495–505.
5. Hulkkonen S, Shiri R, Auvinen J, Miettunen J, Karppinen J, Ryhänen J. Risk factors of hospitalization for carpal tunnel syndrome among the general working population. *Scand J Work Environ Health* 2020;**46**:43–49.
6. Harris-Adamson C, Eisen EA, Kapellusch J *et al*. Occupational risk factors for work disability following carpal tunnel syndrome: a pooled prospective study. *Occup Environ Med* 2022;**79**:442–451.
7. Harris-Adamson C, Eisen EA, Dale AM *et al*. Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. *Occup Environ Med* 2013;**70**:529–537.
8. Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies. *Obes Rev* 2015;**16**:1094–1104.
9. Shiri R. A square-shaped wrist as a predictor of carpal tunnel syndrome: a meta-analysis. *Muscle Nerve* 2015;**52**:709–713.
10. Pourmemari MH, Shiri R. Diabetes as a risk factor for carpal tunnel syndrome: a systematic review and meta-analysis. *Diabet Med* 2016;**33**:10–16.
11. Hassan A, Beumer A, Kuijer PPFM, van der Molen HF. Work-relatedness of carpal tunnel syndrome: systematic review including meta-analysis and GRADE. *Health Sci Rep* 2022;**5**:e888.
12. Palmer KT. Carpal tunnel syndrome: the role of occupational factors. *Best Pract Res Clin Rheumatol* 2011;**25**:15–29.
13. Harris-Adamson C, Eisen EA, Kapellusch J *et al*. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of 2474 workers. *Occup Environ Med* 2015;**72**:33–41.
14. Violante FS, Farioli A, Graziosi F *et al*. Carpal tunnel syndrome and manual work: the OCTOPUS cohort, results of a ten-year longitudinal study. *Scand J Work Environ Health* 2016;**42**:280–290.
15. Violante FS, Armstrong TJ, Fiorentini C *et al*. Carpal tunnel syndrome and manual work: a longitudinal study. *J Occup Environ Med* 2007;**49**:1189–1196.
16. Lund CB, Mikkelsen S, Thygesen LC, Hansson GA, Thomsen JF. Movements of the wrist and the risk of carpal tunnel syndrome: a nationwide cohort study using objective exposure measurements. *Occup Environ Med* 2019;**76**:519–526.
17. Mondelli M, Curti S, Mattioli S *et al*. Associations between body anthropometric measures and severity of carpal tunnel syndrome. *Arch Phys Med Rehabil* 2016;**97**:1456–1464.
18. Mondelli M, Curti S, Farioli A *et al*. Anthropometric measurements as a screening test for carpal tunnel syndrome: receiver operating characteristic curves and accuracy. *Arthritis Care Res (Hoboken)* 2015;**67**:691–700.
19. Mondelli M, Farioli A, Mattioli S *et al*. Severity of carpal tunnel syndrome and diagnostic accuracy of hand and body anthropometric measures. *PLoS One* 2016;**11**:e0164715.
20. Ghasemi F, Gholamizadeh K, Rahmani R, Doosti-Irani A. Prevalence and severity of carpal tunnel syndrome symptoms among Iranian butchers and their association with occupational risk factors: implications for ergonomic interventions. *Work* 2020;**66**:817–825.
21. Seror P, Seror R. Hand workload, computer use and risk of severe median nerve lesions at the wrist. *Rheumatology (Oxford)* 2012;**51**:362–367.
22. Shields LBE, Iyer VG, Daniels MW, Zhang YP, Shields CB. Impact of occupations and hobbies on the severity of carpal tunnel syndrome: an electrodiagnostic perspective. *J Occup Environ Med* 2023;**65**:655–662.
23. Tonga F, Bahadir S. The factors associated with carpal tunnel syndrome severity. *Turk Neurosurg* 2022;**32**:392–397.
24. Mondelli M, Aretini A, Ginanneschi F, Greco G, Mattioli S. Waist circumference and waist-to-hip ratio in carpal tunnel syndrome: a case-control study. *J Neurol Sci* 2014;**338**:207–213.
25. Rempel D, Evanoff B, Amadio PC *et al*. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. *Am J Public Health* 1998;**88**:1447–1451.
26. American Academy of Neurology. Practice parameter for carpal tunnel syndrome (summary statement). Report of the quality standards subcommittee of the American Academy of Neurology. *Neurology* 1993;**43**:2406–2409.
27. *ISCO 88 (COM) - The European Union Variant of ISCO 88 (International Standard Classification of Occupations)*. http://www2.warwick.ac.uk/fac/soc/ier/research/isco88/ (29 February 2024, last date accessed).
28. Mattioli S, Baldasseroni A, Bovenzi M *et al*. Risk factors for operated carpal tunnel syndrome: a multicenter population-based case-control study. *BMC Public Health* 2009;**9**:343.
29. Apostoli P, Sala E, Curti S, Cooke RM, Violante FS, Mattioli S. Loads of housework? Biomechanical assessments of the upper limbs in women performing common household tasks. *Int Arch Occup Environ Health* 2012;**85**:421–425.
30. Giannini F, Cioni R, Mondelli M *et al*. A new clinical scale of carpal tunnel syndrome: validation of the measurement and clinical-neurophysiological assessment. *Clin Neurophysiol* 2002;**113**:71–77.
31. Padua L, LoMonaco M, Gregori B, Valente EM, Padua R, Tonali P. Neurophysiological classification and sensitivity in 500 carpal tunnel syndrome hands. *Acta Neurol Scand* 1997;**96**:211–217.
32. Breslow NE, Day NE. *Statistical Methods in Cancer Research (Volume 1)*. Lyon: International Agency for Research on Cancer, 1980.
33. Möllestam K, Englund M, Atroshi I. Association of clinically relevant carpal tunnel syndrome with type of work and level of education: a general-population study. *Sci Rep* 2021;**11**:19850.
34. Chiotis K, Dimisianos N, Rigopoulou A, Chrysanthopoulou A, Chroni E. Role of anthropometric characteristics in idiopathic carpal tunnel syndrome. *Arch Phys Med Rehabil* 2013;**94**:737–744.
35. Mondelli M, Aprile I, Ballerini M *et al*. Sex differences in carpal tunnel syndrome: comparison of surgical and non-surgical populations. *Eur J Neurol* 2005;**12**:976–983.
36. Nambiema A, Bertrais S, Bodin J *et al*. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: results from the French Pays de la Loire study. *BMC Public Health* 2020;**20**:456.