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**Attributable Risk of Carpal Tunnel Syndrome in the General Population: Implications for Intervention Programs in the Workplace**

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**ABSTRACT:**

**Objectives** Carpal tunnel syndrome (CTS) represents one of the most significant and costly health problems occurring in the working population. Estimation of the potential impact of prevention programs for CTS in the workplace would be useful for public policy. The aim of this study was to assess the population attributable fraction (PAF) of CTS to work according to the main industry sectors and occupation categories at high risk of CTS in a general population.

**Methods** All cases of CTS occurring among patients living in a French region were included prospectively from 2002 to 2004. Medical and occupation history was gathered from 815 women and 320 men by mailed questionnaire. Age-adjusted relative risks and PAFs of CTS were computed in relation to industry sectors and occupation categories.

**Results** The PAF for women was higher in lower-grade white-collar workers (24% [19-29]) than in blue-collar workers (19% [15-22]). PAF was higher for the service industries sector (16% [8-22]) than for manufacturing (10% [7-13]) or agriculture (5% [3-7]) sectors. For men, the PAF was high in male blue-collar workers (50% [41-57]) and in the construction (13% [9-18]) and manufacturing industries (17% [10-23]).

**Conclusion** The study suggested that in theory up to 5 to 50% of cases of CTS might be avoided in the whole population if totally effective intervention programs were implemented in specific occupational categories or industry sectors.

**Key terms:** burden of disease; carpal tunnel syndrome; population attributable risk; prevention; work; work-related

**Short title: Attributable Risk of Carpal Tunnel Syndrome**

## **Introduction**

Carpal tunnel syndrome (CTS) represents one of the most significant and costly health problems occurring in the working population world-wide (1). Epidemiological studies have identified several combinations of personal and work-related risk factors for CTS (1, 2). Most of the work-related risk factors for CTS are more modifiable than individual risk factors, and the implementation of intervention programs in the workplace is expected to reduce the burden of CTS in the population (1). Using the results of a large survey of musculoskeletal disorders and their risk factors in the working population of the Pays de la Loire region, we recently calculated that up to 31% of cases in manual workers could theoretically be prevented by lowering the levels of physical work exposure in that population (3). The proportion of avoidable work-related musculoskeletal disorders (WR-MSDs) is less in the whole working population (4).

In France, as in many countries, information regarding CTS and its risk factors at the population level is still scanty, although more information is available at the workplace level (5). The French Institute for Public Health Surveillance (InVS) therefore implemented an epidemiological surveillance system for CTS in the general population of the Maine-et-Loire region in West-Central France in 2002 to assess the risk of CTS according to industry and occupation and the proportion of cases attributable to work. Recently reported (6) results showed a higher incidence rate of CTS in employed than in unemployed persons with highest risks for two occupation categories (lower-grade white-collar workers for women and blue-collar workers for both genders) and four major industries (agriculture and service industries for women, manufacturing for both genders, construction for men). Assuming that other risk factors remain unchanged and that there is a causal relationship between work exposure and CTS, the population attributable fractions of CTS to work (PAF) in high risk industries and occupations should reveal the proportion of CTS cases that might be prevented following

reduction of the risk of CTS at the workplace level (7). Such information thus provides an estimation of the theoretically maximum potential impact of the prevention programs of CTS in the workplace (8). This would be particularly useful for public policy and prevention programs and for selecting which sectors or occupations require intervention. Our aim in this study was therefore to assess the PAFs of CTS according to the main industry sectors and occupation categories characterized by a high risk of CTS in a French general population.

## **Methods**

### **Protocol**

*Population:* The population included in the CTS surveillance program comprised residents of the Maine-et-Loire region in the 20-59 age group [194,276 women and 193,802 men]. According to the French National Institute of Statistics and Economic Studies (INSEE) census of 1999, the economic structure of the region was diversified and similar overall to that of most French regions, except Paris. The main sectors were distributed as follows: agriculture (women, 6%; men, 11%), construction (women, 1%; men, 10%), manufacturing (women, 18%; men, 27%) and service industries (women, 75%; men, 52%). The employment rate was 66% for women and 81% for men.

*Outcome definition:* Subjects who had undergone electrodiagnostic studies (EDS) of the upper-limbs by all five physicians working at the only four electrodiagnostic centers of the Maine-et-Loire region were eligible for the study if they were residents of the defined geographic area. Only cases of CTS without prior history of CTS of the same wrist were included prospectively between 2002 and 2004. All incident cases of CTS were defined by both clinical and electrophysiological criteria using the same standardized protocol, which followed published recommendations (9,10). To be included, symptoms had to be classified as classic/probable CTS using the Katz hand diagram (9) and at least two of the following

EDS criteria were required (10): delay in the distal motor latency of the median nerve, decrease in sensory conduction velocity of the median nerve, decrease in amplitude of the sensory potentials or a relative delay in sensory distal latency of the median nerve compared with the ulnar nerve. See Roquelaure et al (6) for details.

*Inclusion and data collection procedure:* Each eligible patient was informed of the study by the physician and signed a consent form after the clinical examination and EDS. Medical history, including prior history of CTS, hand symptoms, and the conclusion regarding the EDS of the median nerve(s) were reported to our laboratory. A self-administered questionnaire was then mailed to each subject. Information was collected on medical and surgical history (obesity defined by body mass index (BMI) >30 kg/m<sup>2</sup>, diabetes mellitus, thyroid disorders, gynaecological history, wrist/hand trauma, prior CTS, and upper limb musculoskeletal disorders) and employment (industry, occupation and description of tasks during the preceding 5 years). See Roquelaure et al (6) for details.

*Coding of occupations.* Jobs were coded for Economic activity of the employers (NAF) and occupation (PCS), using the one-digit codes of the French version of the European Community Activities Nomenclature (NAF codes, 4 classes) and the French classification of occupations (PCS codes, 8 classes). The lower-grade white-collar category includes employees of trade and commerce (e.g., cashiers) and personal services (e.g., hairdressers and waitresses), and lower-grade government executive officials and public service workers (e.g., school cleaners, nurses' aides and lower-grade public office workers). The blue-collar category includes material handlers, skilled and unskilled industrial workers (e.g., machine operators and food operators), skilled and unskilled craft workers (e.g., plumbers and bricklayers), and unskilled agricultural workers (e.g., horticulture and vineyards workers).

## Analysis

The characteristics of the general population of the M&L region were extracted from the 1999 INSEE census, which was the last available census at the time of the study. Incidence rates were estimated per patient and not per wrist, so that any patient with bilateral CTS was regarded as one case. The date of the EDS study was used to define the date of diagnosis of CTS, because the date of onset of symptoms was imprecise or not available for about 30% of cases.

Age- and gender-specific annual incidence rates were computed with the number of persons suffering from CTS newly diagnosed during the year under consideration as numerator. Assuming that the general population remained stable, the denominator was an estimate of the average number of person-years during the same period based on the 1999 INSEE census data<sup>11</sup>. The age-adjusted relative risks (RR) of CTS according to industry sectors and occupation categories were computed using the Mantel-Haenszel method with the whole sample of subjects included in the study as reference, whether they were employed at the time of diagnosis or not. The non working subjects included both subjects who had never worked, mainly women, pensioners and all unemployed subjects in the year of diagnosis or the year of the census. Subsequently, the population attributable fraction of risk (PAF [%]) to work in the occupation category (or industry sector) under consideration was computed using the following formula (11):

$$PAF = Pe (RR-1) / [Pe (RR-1) + 1] \quad (\text{equation 1})$$

The PAF takes into consideration the proportion of subjects involved in the general population (Pe [%]) and represents the proportion of cases of CTS in the whole population for each gender which could be avoided if the occupation category under consideration (or industry sector) did not expose to an excess of risk of CTS (11).

## Results

A total of 1,168 cases (819 women, 349 men; male:female ratio 1:2.3), corresponding to 1,644 wrists affected by CTS, were included during the 3-year period. Medical and surgical history and employment status were available for the 815 women and 320 men who completed the questionnaire. Mean age was 44.9 (SD 9.4) years in women and 43.3 (SD 9.5) years in men. The population-based annual incidence rates of CTS were 1.4 for 1,000 females and 0.6 for 1,000 males, and increased substantially with age for both genders ( $P < 0.001$ ). The prevalence of obesity (16 %) and diabetes mellitus (4%) were similar between men and women. The prevalence of thyroid disorders was high only in women (13%). Furthermore, 20% of men and 30% of women had obesity, diabetes mellitus, or thyroid disorders, without significant differences according to industry or occupational categories.

About 79% of women and 89% of men suffering from CTS were working at the time of diagnosis and 90% of women and 97% of men had worked in the 5-year period before the diagnosis. The mean length of employment in the last job was 7 years, without difference between men and women. Most men (71%) and women (62%) had the same job during the last five years. Few men had occupied two (13%) or more (8%) during this period, the corresponding values for women being 16% and 10%. In most of these cases, the changes of occupation in the period preceding the diagnosis did not modify the industry sector and occupation category. The excess risk of CTS was statistically significant for two main occupational categories: blue-collar workers (for both genders) and lower-grade services, sales and clerical white-collar workers (for women) (table 1). Among female blue-collar workers, the excess risk of CTS concerned mainly skilled blue-collar workers (RR = 3.2 [2.7-3.8]) and unskilled agricultural workers (RR= 4.2 [3.2-5.7]). Among male blue-collar



workers, the excess risk of CTS involve skilled (RR = 1.8 [1.5-2.3]) and unskilled (RR = 3.5 [2.7-4.5]) blue-collar workers and unskilled agricultural workers (RR= 3.5 [2.2-5.5]).

In terms of industry sectors, work in agriculture (for women), manufacturing (for both genders), construction (for men) and service industries (for women) was associated with an excess risk of CTS (table 2). Among women, this latter sector mainly involved blue-collar and lower-grade white-collar workers (84%); among men, service industries involved blue-collar workers (49%) and also a relatively large percentage (29%) of qualified white-collar workers and professionals.

The PAF of CTS for male blue-collar workers reached 50% (table 1), suggesting that more than half of CTS cases diagnosed in the population could be avoided if the excess risk of CTS in blue-collar workers could be eliminated. Considering the subcategories of blue-collar workers in men at high risk of CTS, PAFs were 15.7 [8.8-22.1] in skilled workers, 20.9 [15.3-26.1] in unskilled workers and 6.9 [3.6-10.2] in agricultural workers. The PAF was lower for female blue-collar workers (19%), but reached a higher value (24%) for female lower-grade services, sales and clerical white-collar workers. Considering the two subcategories of blue-collar workers at high risk of CTS in women, the PAFs were 13.2 [10.2-16.0] in unskilled workers and 5.0 [3.6-6.7] in agricultural workers.

The PAF for women was higher for the service industries sector (16%), which is the largest industry sector in the region, than for the manufacturing (10%) or agriculture (5%) sectors. For men, the PAF was relatively high for two sectors: construction (13%) and manufacturing (17%) (table 2).

## **Discussion**

The strength of this study is the inclusion of incident cases of CTS in the general population reported by a sentinel surveillance network of physicians covering almost all the inhabitants of the region, irrespective of their employment status. The organization, efficacy and representativeness of the CTS surveillance network are discussed elsewhere (6). Schematically, the network suffered from a lack of exhaustiveness because of several factors. For example, some people living in the Maine-et-Loire area might have undergone electrodiagnostic studies in an area not covered by the network. A few eligible subjects refused to sign the consent form for various reasons, mainly lack of time. The participation of the sentinel physicians over the 3-year period was uneven since one physician notified us of very few cases and another left the network in 2003 for personal reason. In addition, some eligible cases were not included by physicians because of lack of time. However, no significant differences regarding age, gender and last occupation were observed between the patients included in our study and those treated surgically in the same area (6). This indicates that there was no systematic inclusion bias of CTS cases in the surveillance program reported here according to age, gender, employment status and last occupation. Consequently, even if the incidence of CTS was underestimated, estimates of RRs of CTS according to industry sector and occupation category should be considered as unbiased, and the estimate of PAF of CTS as accurate. See reference (6) for details.

Work exposure was appraised at the industry and the job title level without in-plant job analysis, and therefore no precise assessment of the actual exposure to biomechanical and psychosocial risk factors of CTS was performed. The collection and coding of occupational and economic activity information relied on detailed information on the jobs and tasks using a methodology comparable to that of the INSEE census. Most patients were professionally active during the five years period before the diagnosis and at the time of the diagnosis. Length of service was high and most workers had remained in the same occupation during the

previous five years. Moreover, when occupational changes occurred, very few shifts from one occupational category (or industry sector) to another one were observed. We checked that the results were similar using three slightly different definitions for occupation: occupation at the time of the surgery, last occupation in the five years before surgery, and longest occupation in the 5-year period. This is consistent with the fact that the latest occupation was also the longest one for most patients. CTS cases in 2002-2004 were compared to the 1999 census and some changes could have occurred in the population between 1999 and 2004. Nevertheless, the length of service in the last job was high and most workers did not shift from one occupational category (or industry sector) to another one between 1999 and 2004.

The reference group was enlarged to the whole sample of subjects. Consequently, the age-adjusted RRs and the PAFs of CTS in specific industries and occupation categories were underestimated because the comparison group included a substantial proportion of industrial and occupational groups at high risk of CTS (12). Analyses were controlled for age and gender, but not for other potential confounding factors related to occupational and non-occupational risk factors of CTS (1) since only limited information on the medical history was available. Both diabetes mellitus and obesity were twice more frequent among cases than in the general population of the region, which agrees with surveys of CTS in the general population (1). Nevertheless, the prevalence of obesity and diabetes among cases did not differ drastically between industries and occupations (6). The data available in the general population of this area did not allow more precise analysis of the relative role of obesity and occupation on the risk of CTS. No information was available on non-occupational physical activities, such as housework, leisure and sports activities. Some of them, such as housework among women, may be more prevalent in the lower income categories, and therefore be a confounding factor for the association between CTS and blue-collar occupations. However,

except for sex and age, which were taken into account in the analyses, the non-occupational causes of CTS seem unlikely to play a major role as confounding factors (1, 2, 13).

PAF data reported in the Maine-et-Loire region should be treated with caution since the values could be different in populations with different socio-economic characteristics, depending on the proportions ( $P_{e [%]}$ ) of blue- and white-collar workers and the sizes of the industry sectors, even if the relative risks of CTS were similar (11). Nevertheless, the socioeconomic structure of the Maine-et-Loire region is comparable to those of most French regions, except Paris (1999 INSEE census). At the workplace level, the attributable risk of CTS could be different, since wide variations in exposure to work constraints may exist between companies in the same industry sector (5).

The computation of the potential impact of intervention strategies assumed several hypotheses, namely a causal relationship between the occurrence of CTS and work exposure (1, 2, 11, 14) and a substantial impact of prevention intervention. Although multidimensional ergonomic workplace intervention programs to prevent CTS appear to be effective (1), only limited evidence of their efficacy is available (15). Moreover, insufficient information is available on the temporal and quantitative relationships between the decrease in exposure to repetitive and forceful constraints following large intervention studies and the decrease in the incidence of CTS (1, 8, 16).

Our findings on the industry sectors at high risk of CTS in the region are in line with the epidemiological literature (1, 17). Work in the service industries was associated with a higher risk of CTS in women and a lower risk in men. This might be explained by the gender division of work in this sector, with most of the women in the two lowest occupational categories (at high risk of CTS), whereas many men belonged to high-grade occupation categories.

The excess risk of CTS was only statistically significant for lower grade occupation categories: blue-collar workers for men and women and lower-grade services, sales and clerical white-collar workers for women. The estimates of RR for blue-collar workers were in the same order of magnitude as those calculated in the only comparable study (the Montreal study) comparing the incidence of surgical release of the median nerve between manual and non-manual workers in 1994-5 (12).

Despite its value from the public health viewpoint, very little has been published in the literature assessing the PAF of CTS to work (18). This indicator would be valuable for public policy, because it describes the proportion of cases occurring in the population which could theoretically be avoided if the industries or occupations considered did not result in an excess of risk of CTS. Our study shows that half of male and a fifth of female cases of CTS could theoretically be avoided in the general population if such interventions were implemented for blue-collar workers. For female lower-grade white-collar workers, almost a quarter of cases could be avoided.

For women, the attributable proportion of CTS cases of lower-grade white-collar workers was greater than that of blue-collar workers, despite a lower risk of CTS. Similarly, the impact of the service industries on the burden of female CTS was greater than that of the manufacturing sector. This confirms that intervention programs must be targeted not only in terms of the level of risk but also of the number of workers involved. Our results thus suggest focusing prevention on blue-collar occupations for men, and on blue-collar and overall lower-grade white-collar occupations for women. More precisely, intervention programs should focus on the blue-collar workers of the manufacturing (for both genders) and construction sectors (for men), and on the female lower-grade white-collar workers of the service industries (e.g., cashiers, hairdressers, nurses' aides).

In France, as in several countries, WR-MSDs are a national priority and many preventive intervention programs have been implemented at the company level. Although our study did not attempt to evaluate intervention programs, it suggests that the maximum theoretical impact of programs for prevention of CTS in the whole population might be between 5 and 50% if totally effective intervention programs were to be implemented in specific occupational categories or industry sectors. However, reducing the risk of CTS in manual workers performing repetitive or forceful movements to the mean level of the general population is probably unrealistic, and more realistic objectives should probably be targeted (3, 4).

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**TABLE 1-Relative risks and attributable risk fractions in population of CTS according to occupation categories**

OCCUPATION CATEGORY (PCS CODE) <sup>a,b</sup>	Pe (%)	N (%)	RR [CI <sub>95%</sub> ]	PAF (%) [CI <sub>95%</sub> ] <sup>d</sup>
<b>WOMEN</b>				
1. Farmers	1.9	19 (2.3)	1.0 [0.6-1.5]	-
2. Craftswomen, saleswomen and managers	2.3	10 (1.2)	0.5 [0.3-0.9]	-
3. Professionals	4.3	23 (2.8)	0.7 [0.5-1.0]	-
4. Technicians, associate professionals	14.2	64 (7.8)	0.6 [0.4-0.7]	-
5. Lower grade white-collar workers	30.5	384 (46.8)	2.0 [1.8-2.3]	23.8 [18.7-28.5]
6. Blue-collar workers	12.4	234 (28.5)	2.9 [2.5-3.4]	18.9 [15.3-22.4]
7-8. Pensioners and other non-working persons	34.4	80 (9.8)	0.2 [0.2-0.3]	-
<b>MEN</b>				
1. Farmers	4.8	14 (4.4)	1.2 [0.7-2.1]	-
2. Craftsmen, salesmen and managers	6.3	13 (4.1)	0.6 [0.3-1.0]	-
3. Professionals	9.1	17 (5.3)	0.7 [0.4-1.2]	-
4. Technicians, associate professionals	16.7	29 (9.2)	0.5 [0.4-0.8]	-
5. Lower grade white-collar workers	7.8	24 (7.6)	1.3 [0.8-2.0]	-
6. Blue-collar workers	35.9	210 (66.7)	3.8 [3.0-4.7]	49.7 [41.3-56.8]
7-8. Pensioners and other non-working persons	19.4	10 (3.1)	0.2 [0.1-0.4]	-

*Note.* <sup>a</sup> Persons working during the 5- year period before the diagnosis; Pe (%): percentage in the general population of the Maine-et-Loire area; N (%): number and distribution of CTS incident cases by occupation category; CI<sub>95%</sub>: 95% confidence interval; <sup>b</sup> Unspecified categories: 6 for women (0.7%) and 4 for men (1.3%); <sup>d</sup> range computed using the lower and upper limits of the confidence interval of the RR of CTS in equation (1).

**TABLE 2-Relative risks and attributable risk fractions in population of CTS according to industry sectors**

<b>INDUSTRY SECTOR (NACE code)<sup>a,b,c</sup></b>	<b>Pe (%)</b>	<b>N (%)</b>	<b>RR [CI<sub>95%</sub>]</b>	<b>PAF (%) [CI<sub>95%</sub>]<sup>d</sup></b>
<b>WOMEN</b>				
1. Agriculture	4.0	80 (9.8)	2.4 [1.9-3.0]	5.2 [3.1-7.2]
2. Construction	0.7	6 (0.7)	2.3 [1.0-5.2]	-
3. Manufacturing	11.5	166 (20.4)	2.0 [1.7-2.4]	10.3 [7.1-13.4]
4. Service industries	49.5	477 (58.5)	1.4 [1.2-1.6]	16.0 [8.9-22.0]
<b>MEN</b>				
1. Agriculture	8.7	34 (10.6)	1.3 [0.9-1.9]	-
2. Construction	8.2	63 (19.7)	2.9 [2.2-3.8]	13.3 [8.4-18.0]
3. Manufacturing	22.0	115 (35.9)	1.9 [1.5-2.4]	17.0 [10.0-23.5]
4. Service industries	41.8	93 (29.1)	0.5 [0.4-0.7]	-

*Note.* <sup>a</sup> Persons working during the 5- year period before the diagnosis; ; Pe (%): percentage in the general population of the Maine-et-Loire area; N (%): number and distribution of CTS incident cases by industry sectors; CI<sub>95%</sub>: 95% confidence interval; <sup>b</sup> Unspecified sector: 1 for women (0.1%) and 3 for men (1.0%); <sup>c</sup> Non-working persons haven't Nace code (80 women and 10 men); <sup>d</sup> range computed using the lower and upper limits of the confidence interval of the RR of CTS in equation (1).

**TABLE 1-Relative risks and attributable risk fractions in population of CTS according to occupation categories**

OCCUPATION CATEGORY (PCS CODE) <sup>a,b</sup>	Pe (%)	N (%)	RR [CI <sub>95%</sub> ]	PAF (%) [CI <sub>95%</sub> ] <sup>d</sup>
<b>WOMEN</b>				
1. Farmers	1.9	19 (2.3)	1.0 [0.6-1.5]	-
2. Craftswomen, saleswomen and managers	2.3	10 (1.2)	0.5 [0.3-0.9]	-
3. Professionals	4.3	23 (2.8)	0.7 [0.5-1.0]	-
4. Technicians, associate professionals	14.2	64 (7.8)	0.6 [0.4-0.7]	-
5. Lower grade white-collar workers	30.5	384 (46.8)	2.0 [1.8-2.3]	23.8 [18.7-28.5]
6. Blue-collar workers	12.4	234 (28.5)	2.9 [2.5-3.4]	18.9 [15.3-22.4]
- Skilled blue-collar workers	. 3.9	. 34	. 1.2 [0.9-1.7]	. 0.9 [0.0-2.4]
- Unskilled blue-collar workers	. 6.9	. 152	. 3.2 [2.7-3.8]	. 13.2 [10.2-16.0]
- Unskilled agricultural workers	. 1.6	. 48	. 4.2 [3.2-5.7]	. 5.0 [3.2-6.7]
7-8. Pensioners and other non-working persons	34.4	80 (9.8)	0.2 [0.2-0.3]	-
<b>MEN</b>				
1. Farmers	4.8	14 (4.4)	1.2 [0.7-2.1]	-
2. Craftsmen, salesmen and managers	6.3	13 (4.1)	0.6 [0.3-1.0]	-
3. Professionals	9.1	17 (5.3)	0.7 [0.4-1.2]	-
4. Technicians, associate professionals	16.7	29 (9.2)	0.5 [0.4-0.8]	-
5. Lower grade white-collar workers	7.8	24 (7.6)	1.3 [0.8-2.0]	-
6. Blue-collar workers	35.9	210 (66.7)	3.8 [3.0-4.7]	49.7 [41.3-56.8]
. Skilled blue-collar workers	. 22.1	. 109	. 1.8 [1.5-2.3]	. 15.7 [8.8-22.1]
. Unskilled blue-collar workers	. 10.7	. 80	. 3.5 [2.7-4.5]	. 20.9 [15.3-26.1]
. Unskilled agricultural workers	. 3.0	. 20	. 3.5 [2.2-5.5]	. 6.9 [3.6-10.2]
7-8. Pensioners and other non-working persons	19.4	10 (3.1)	0.2 [0.1-0.4]	-

*Note.* <sup>a</sup> Persons working during the 5- year period before the diagnosis; Pe (%): percentage in the general population of the Maine-et-Loire area; N (%): number and distribution of CTS incident cases by occupation category; CI<sub>95%</sub>: 95% confidence interval; <sup>b</sup> Unspecified categories: 6 for women (0.7%) and 4 for men (1.3%); <sup>d</sup> range computed using the lower and upper limits of the confidence interval of the RR of CTS in equation (1).