

ATTRIBUTABLE RISK OF CARPAL TUNNEL SYNDROME ACCORDING TO INDUSTRY AND OCCUPATION IN A GENERAL POPULATION

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KEY WORDS. Attributable risk fraction; Carpal tunnel syndrome; Industry; Occupation; Work; Work-related.

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ABSTRACT (223 words)

Objectives. An epidemiological surveillance network for carpal tunnel syndrome (CTS) was set up in the general population of a French region to assess the attributable fraction of CTS according to work in high risk industries and occupations.

Methods. Cases of CTS occurring among patients aged 20 to 59 living in the Maine and Loire region were included prospectively from 2002 to 2004. Medical and occupation history was gathered by mailed questionnaire for 815 women and 320 men. Age-adjusted relative risks of CTS and the attributable fractions of CTS to work among exposed persons (AFE) were computed in relation to industry sectors and occupation categories.

Results. Twenty-one industry sectors and eight occupational categories for women, and ten sectors and six occupational categories for men were characterized by a significant excess risk of CTS. High values of AFE were observed in the manufacturing (from 42 to 93% for both genders), construction (66% for men) and personal service industries (66% for women), and trade and commerce (49% for women) sectors. High values of AFE were observed in female lower grade white-collar occupations (from 43 to 67%), and male (from 60 to 74%) and female (from 48 to 88%) blue-collar occupations.

Conclusion. The attributable fractions of CTS among workers employed in industry sectors and occupation categories identified at high risk of CTS varied between 36 and 93%.

Carpal tunnel syndrome (CTS) is a common clinical problem with annual incidence rates estimated between 0.5 and 5.1 per 1,000 for CTS defined by electrophysiological criteria (1-3) and 0.4 to 1.5 per 1,000 for CTS requiring surgical release of the median nerve (4,5). Epidemiological studies have identified several combinations of work factors, individual factors and psychosocial factors related to CTS (6). Female gender, obesity, pregnancy, and medical conditions including diabetes mellitus, thyroid disease, wrist osteoarthritis, and any form of inflammation affecting the wrist joints or tendon sheaths have been reported to have an increased risk of CTS (6-8). In terms of work exposure, repetitive and forceful exertions of the hand, sustained awkward postures of the wrist, and use of vibrating hand tools are associated with an excess of risk of CTS (6).

CTS represents a leading cause of upper extremity musculoskeletal disorders, which are among the most significant and costly health problems occurring in the working population world-wide (6). Although not uniquely caused by work, CTS represents a major proportion of all registered or compensatable work-related diseases in many countries (6,9,10). Since many of the individual risk factors of CTS are less modifiable than workplace factors, information about the occupations and industries in which workers develop CTS is essential to target prevention strategies. Estimation of the attributable risk of CTS according to occupation and specific workplace risk factors would provide information on the impact of the risk excess of CTS in the population. This would have important implications for public policy and prevention programs and for selecting which sectors or occupations require interventions (11).

The French Institute for Public Health Surveillance (InVS) therefore implemented an epidemiological surveillance system for CTS in the general population of the Maine and Loire region in West-Central France in 2002. Results recently reported (12) show a higher incidence rate of CTS in employed than unemployed persons. A substantial proportion of CTS diagnosed among two major occupation categories (lower-grade white-collar workers for women and blue-collar workers for both gender) and four major industries (agriculture for women, manufacturing

for both genders, construction for men and services industries for women) were attributable to work. These results are insufficiently precise to determine public policy and target the prevention interventions on the sectors and occupations at highest risk of CTS. Therefore, our aim in this study was, by the use of a more refined classification of industry sectors and occupation categories, to assess in detail the attributable fraction of risk of CTS according to the industry sectors and occupation categories and subcategories characterized by a high risk of CTS.

METHODS

Protocol

Population: The population included in this study comprised all residents of the Maine and Loire region between the ages of 20-59 [194,276 women (50.1%) and 193,802 men (49.9%)]. According to French National Institute of Statistics and Economic Studies (INSEE) census of 1999, the economic structure was diversified and similar overall to that of most French regions, except Paris. Most of the industry sectors taken into consideration by the European Statistical Classification of Economic Activities (2-digit NACE code) were present in the region, except mining of uranium and thorium ores. The main sectors were distributed as follow: 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 any physician (N = 5) who worked at the only four electrodiagnostic centers of the Maine and 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 (13,14). To be included, symptoms had to be classified as classic/probable CTS using the Katz hand diagram (14) and at least two of the following EDS criteria were required: a delay in the distal motor latency of the median nerve, a decrease in sensory conduction velocity of the median nerve, a 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 reference (12) 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 on 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, diabetes mellitus, thyroid disease, gynecological history, wrist/hand trauma, prior CTS, and upper-limb musculoskeletal disorders) and employment (industry, occupation and description of tasks during the preceding 5 years). The response rate to the questionnaire was 97%. See reference (12) for details.

Coding of occupations. Each occupation during the last 5 years was coded according to industry sectors and occupation categories using the two-digit codes of the French version of the European Community Activities Nomenclature (NAF codes, 58 classes studied), and the two- (31 classes studied) and four-digit (497 classes) French classification of occupations (PCS codes).

Analysis

The characteristics of the general population of the Maine and Loire region were extracted from the 1999 INSEE census. Incidence rates were estimated by patient and not by wrist, so that each patient with bilateral CTS was regarded as one case. The date of the EDS was used to define the date of diagnosis of CTS, because the date of the onset of symptoms was inaccurate or not

available for about 30% of cases. When the workers had had more than one occupation during the preceding 5 years, the analysis was performed on the most recent. If they were unemployed at the time of the diagnosis but employed during the last 5 years, the last occupation was taken into consideration. In cases of unemployment during the preceding 5 years, people (e.g. housewives) were considered as non-working.

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 of the same age and gender during the same period based on the 1999 INSEE census data. The age-adjusted relative risks (RR) of CTS according to industry sectors and occupation categories were computed using the Mantel-Haenzel method with the whole sample of subjects included in the study as a reference, whether they were employed at the time of diagnosis or not. The attributable fractions of disease among those employed in a certain industry sector or occupation category or subcategory (AFE [%]) (15) were computed to estimate the fractions of CTS cases attributable to work in the industries and occupations at high risk (when at least 5 cases of CTS occurred) using the following formula (see Appendix A for details on the computation of the 95% confidence interval of the AFE):

$$AFE = (RR-1) / RR \quad (\text{equation 1})$$

Statistical analyses were performed using SPSS 13.0 software.

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 only available for the 815 women and 320 men who completed the questionnaire.

Mean age was 44.9 (SD 9.3) yrs and 43.3 (SD 9.5) yrs in women and men, respectively. The population-based annual incidence rates of CTS were 1.4 for 1,000 females and 0.6 for 1,000 males. The incidence of CTS increased with age ($P < 0.001$) for both genders (Table 1). About 81% of women and 90% of men suffering from CTS were working at the time of diagnosis. A total of 30% of women and 20% of men had obesity ($BMI > 30 \text{ kg/m}^2$), diabetes mellitus, or thyroid disease, without differences according to industry or occupation.

Wide variations in incidence of CTS were observed according to industry sector and occupation category for both genders. Individuals suffering from CTS worked in 48 different industry sectors (out of a total of 58 represented in the region). No cases occurred in sewage and refuse disposal or in some small industry sectors of this region (fishing, mining, manufacture of tobacco products, petroleum and nuclear industries, water and air transport, and research and development). Twenty-three sectors (21 for women and 10 for men) were associated with a significant excess of risk of CTS (Table 2): agriculture, construction and several sectors of the manufacturing and services industries. About 75% of women and 52% of men suffering from CTS worked in these sectors, while they accounted for the employment of 40% of women and 24% of men in the region. Among women, AFEs were over 50% for agriculture and most manufacturing and services industry sectors at high risk of CTS. The highest values were observed for the manufacture of chemical products, metal products and transport equipment. Among men, all AFEs were over 50%, with the highest values for the manufacture of transport equipment, the wood and furniture and the stone carrying sectors.

CTS cases were identified among all occupation categories (out of a total of 31 represented in the region), except for clergymen. No risk excess was observed for farmers, craftsmen, salesmen and managers, professionals, intermediate occupations and technicians. Eight occupation categories (eight for women and six for men), and among them thirty-two subcategories (25 for women and 12 for men), were characterized by a significant risk excess of CTS (Tables 3 and 4). These categories involved both lower grade white-collar workers and blue-collar workers for

women and mainly blue-collar workers for men, accounting for 73% of female and 61% of male cases, whereas they accounted for the employment of 31% of women and 27% of men in the region. The AFEs ranged between 37% and 92% in women, and 65% and 93% in men. Highest values were observed for routine occupations i.e., material handlers, unskilled industrial blue-collar workers (e.g., packers, mechanical-machinery operators and meat- and food-processing machine operators) and unskilled agricultural blue-collar workers (e.g., vineyard workers) of both genders. AFEs were high in skilled craft blue-collar workers for men (e.g., cooks, plumbers, gardeners) and women, and in male unskilled craft blue-collar workers (e.g., male construction laborers). AFEs were high for trade and commerce employees (e.g., cashiers) in women, but remained under 50% for other lower grade white-collar categories, such as employees of government and public services (of both genders), and personal services employees (for women). Nevertheless, AFEs reached higher values for some subcategories, such as nurses' aides and personal care workers, lower grade government clerks, waitresses and hairdressers.

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 inhabitants, irrespective of their employment status. Although the Maine and Loire region is characterized by extensive development of the manufacturing and meat industries and agriculture (vineyards, horticulture and arboriculture), its socioeconomic structure is comparable to those of most French regions (1999 INSEE census). Case definition of CTS was in agreement with recent consensus definitions for epidemiological surveillance of CTS (14). The main limitation of the study was that the lack of exhaustiveness of the sentinel network led to an underestimation of the incidence of CTS. This could be explained by various factors (12). Some people living in the Maine and 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 several 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 reasons. In addition, some eligible cases were not included by the physicians because of lack of time. Such reasons were also reported by a similar sentinel network in the USA (16). The lack of exhaustiveness of the network explains the relatively low estimate of incidence of CTS in this general population compared to those reported in several general populations using electrophysiological definition of CTS (1-3). However, no significant differences were observed between the patients included in our study and those treated surgically regarding age, gender and last occupation (12). 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 relative risk and attributable fraction of CTS according to gender, age and employment status should be unbiased.

Work 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 (17). The reference group was enlarged to the whole sample of subjects which underestimated the age-adjusted RRs and the AFEs of CTS in specific industries and occupation categories, because the comparison group included a substantial proportion of industrial and occupational groups at significantly high risk of CTS (5). The lack of statistical power due to the small number of incident cases in some industries and occupations reduced the accuracy of estimates of RR and AFE. This was particularly true for some sectors, such as publishing, transport, construction (for women), wholesale trade, insurance and pension funding, recreational, cultural and sporting activities, and several occupation subcategories. Moreover, some industries and occupations associated with lower RR might not have been identified. The results should therefore be treated with caution when the number of CTS cases observed was

low. Analyses were controlled for age and gender, but not for other potential confounding factors related to occupational and non-occupational risk factors of CTS (6,7,8,11,18). Only limited information was gathered on the medical history. Nevertheless, the prevalence of the main medical conditions known to increase the risk of CTS were lower than in surgical series (7-8) and did not differ between industries and occupations (12). No information was available on non-occupational physical activities, such as housework, second jobs, non-professional driving, leisure and sport activities. Some of them, such as housework among women, may be more prevalent in categories with the lowest incomes, 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 (6,17,18,19). The estimates of AFE of CTS should be used with caution at the individual level, since they provide information on the imputability of CTS to work at the population level but not at the individual level (15). In particular, AFE does not take into account any individual work characteristics or non-work exposure or medical history which can affect the risk of CTS for each subject (15).

Our study shows that almost all occupation categories at high risk of CTS for men and a large proportion of them for women involved blue-collar workers of the agriculture, manufacturing and construction sectors, which corroborated north-American population-based surveys (1,5,9,16,17,20,21). Among men, significantly high risk of CTS was found not only in semi-skilled and non-skilled industrial workers and machine operators performing routine tasks, but also in skilled craftsmen performing semi-routine tasks (plumbers, bricklayers and gardeners). In accordance with population-based surveys (1,5,9,16,19,20), several categories of lower grade women white-collar workers of the services industry were identified as having a high risk of CTS, namely lower grade white-collar workers of the public services (16), personal services (5,16) and trades (22-24). Few cases of CTS were observed in clerical occupations, and only three lower grade clerical occupation subcategories were at high risk of CTS.

Very little information is available in the literature regarding the proportion of CTS attributable to work. The attributable fraction computed in the present study (AFE) represents the proportion of cases specifically attributable to work in the industry (or occupation) among the cases occurring in individuals working in the industry (or occupation) under consideration (5,25,26). This indicator is useful from a public health view point since it provides information about the proportion of CTS cases in a given occupation that could be avoided if totally effective preventive measures were implemented (15).

A large proportion of CTS cases occurring in the manufacturing sectors were attributable to work. This involved particularly the food, steel, wood, furniture, electronic and automotive industries, which are known to be at high risk of CTS (16,17,20,21,27). In these sectors, the AFE was very high for routine occupations, such as material handlers and several subcategories of industrial blue-collar workers (e.g., mechanical-machine operators, meat- and food-processing operators and packers). Our estimates of AFE for material handlers and food and beverage processing operators were in the same order of the magnitude as those reported in the Montreal study (5), but we report high AFE values in several manufacturing sectors and industrial occupations not identified in that study (5).

The proportion of CTS attributable to work was high, not only for industrial workers but also for skilled and unskilled craft workers, particularly in the construction and mining (stone and sand quarrying) sectors for men. The highest proportions were observed in cooks and occupations characterized by a high physical workload, such as gardeners, plumbers, bricklayers, building construction and finishing labourers (27,28). The AFE of CTS among female cleaners was lower than in the Montreal study (5). The agriculture sector was significantly at high risk of CTS only for women, but the proportion of CTS cases attributable to work was high in non-skilled agricultural occupations for both genders.

The proportion of CTS cases attributable to work in the services industries varied according to the sectors and occupations involved. It was moderate for the retail trade sectors, but reached

higher values in lower grade trade and commerce employees. This could be explained by an underestimation of the AFE of the whole sector because of the dilution of strenuous occupations, such as cashiers and self-service employees, among less physically demanding occupations (16). The same conclusion could be drawn not only for the hotel and restaurant sector and waitress and bartender occupations, but also for the human health and social activities sector and nurses' aides and personal care workers. A substantial proportion of CTS cases were attributable to work in the personal services sector, with high AFE values for lower technical occupations, such as hairdressers. However, the AFE for nursery school assistants and child care workers was half the level reported in the Montreal study (5), as was that for private households with employed persons.

The number of cases reported in administrative sectors, such as insurance and pension funding, was too small to draw clear conclusion. For administrative service lower grade white-collar workers only a small proportion of CTS cases (less than 50%) were attributable to work. The higher values observed for some clerical occupation subcategories, such as lower grade government clerks, should be interpreted with caution due to the small numbers of cases.

CONCLUSION

The attributable proportion of CTS to work among workers employed in the industries and occupations identified at high risk of CTS varied between 36 and 93%. Although the results should be confirmed in other regions, they provide important new insights to evaluate the potential impact of preventive intervention at the population level. Intervention programs must as a priority target companies in high risk sectors and focus preventive efforts on the occupation subcategories most exposed to the risk of CTS.

AUTHOR CONTRIBUTIONS

YR, CH, EI, MG, AD and AL conceived, designed and developed the study protocol, interpreted the results and wrote the manuscript. YR and CM performed the statistical analyses. MCPL and GN performed the electrophysiological testing. GR helped with the recruitment of the patients.

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Appendix A. Computation of the 95% confidence interval $[CI_{95\%}]_{AFE}$ of the attributable fraction of CTS to work among exposed persons (AFE)

The confidence interval of AFE was calculated with the following formula (29):

$$[CI_{95\%}]_{AFE} = 1 - \exp [\ln(1-AFE) \pm 1,96 * \sqrt{(\text{var} \{ \ln(1-AFE) \})}]$$

with:

$$\text{var} \{ \ln(1-AFE) \} = (1/N) * \{ c + AFE * (a+d) \} / b.$$

(N) was the total number of subject in the general population, (a) the number of CTS cases working in the industry sector or occupational category under consideration, (b) the number of subjects with CTS who did not worked in the industry sector or occupational category under consideration, (c) the number of subjects without CTS working in the industry sector or occupational category under consideration, and (d) the number of subjects without CTS who did not worked in the occupational category or industry sector under consideration:

	Exposed [#]	Unexposed [#]	
CTS cases	a	b	m1
Subjects without CTS	c	d	m0
	n1	n0	N

[#] to the industry sector or occupational category under consideration