International Journal of Occupational Medicine and Environmental Health, Vol. 14, No. 4, 357—367, 2001

PREVALENCE, INCIDENCE AND RISK FACTORS OF CARPAL TUNNEL SYNDROME IN A LARGE FOOTWEAR FACTORY

YVES ROQUELAURE[1], JEAN MARIEL[2], CORINNE DANO[1], SERGE FANELLO[1] and DOMINIQUE PENNEAU-FONTBONNE[1]

[1] Center for Occupational Health and Ergonomics
University Hospital
Angers Cedex, France
[2] Occupational Health Service of Anjou
Angers, France

Abstract. The study was conducted to assess the prevalence and incidence of carpal tunnel syndrome (CTS) in a large modern footwear factory and to identify factors predictive of CTS. To this end, 199 workers were examined in 1996, and 162 of them were re-examined in 1997. Ergonomic and psychosocial risk factors of CTS were assessed by workpost analysis and self-administered questionnaire. The prevalence of CTS at baseline in 1996 and in 1997 was 16.6% (95%CI: 11.4–21.7) and 11.7% (95%CI: 6.7–16.8), respectively. The incidence rate of CTS in 1997 was 11.7% (95%CI: 6.7–7.8). No specific type of job performance was associated with CTS. Obesity (OR = 4.4; 95%CI: 1.1–17.1) and psychological distress at baseline (OR = 4.3; 95%CI: 1.0–18.6) were strongly predictive of CTS. Rapid trigger movements of the fingers were also predictive of CTS (OR = 3.8; 95%CI: 1.0–17.2). A strict control of the work by superiors was negatively associated with CTS (OR = 0.5; 95%CI: 0.2–1.3). The prevalence and incidence of CTS in this workforce were largely higher than in the general population and numerous industries. The study highlights the role of psychological distress in workers exposed to a high level of physical exposure and psychological demand.

Key words:
Carpal tunnel syndrome, Follow-up, Physical exposure, Psychosocial factors, Psychological distress, GHQ-12

INTRODUCTION

The incidence of CTS in the North American general population has been estimated to be 0.9 to 3.5 for 1000 person-years [1–3]. CTS affects an increasing number of workers, with the annual incidence in manual workers estimated at 1.9 for 1000 persons [2] and wide variations between sectors. According to prevalence data [4,5], the garment and footwear industries are particularly high risk occupations for CTS [6,7,8]. The footwear industry is the most affected sector in the Pays de la Loire region of France, with the annual incidence of 5.6 workers' compensation (WC) claims for work-related musculoskeletal disorders (WMSDs) per 1000 workers.

Personal risk factors for CTS include several medical disorders and also hormonal changes in women [1,9]. Exposure to physical work factors, such as highly repetitive and/or forceful hand exertion or pinching, repeated flexion, extension or ulnar deviation of the wrist, segmental vibrations and mechanical stress on the base of the palm increase the risk of CTS [5,10]. Work-related psy-

The study was supported by the French Health Insurance Fund for Prevention of Occupational Risks (CNAM-CRAM Pays-de-la-Loire, grant for 1996–2000).
Address reprint requests to Y. Roquelaure MD, Center for Occupational Health and Ergonomics, University Hospital, F-49033 Angrers Cedex, France (e-mail: yvroquelaure@chu-angers.fr).

chosocial factors such as monotonous work, time pressure and high psychological demand enhance the physical and/or the psychological load with which the workers have to cope [11,12]. The work organization, characterized by high psychological demands and poor social support from colleagues or superiors, has been associated with musculoskeletal disorders. The strength of the relationship between CTS and psychosocial factors is found to be lower than that for proximal neck and shoulder disorders [11,13]. Moreover, psychological distress and psychosocial factors may be the result or a cause of musculoskeletal disorders [11] and should be measured before the onset of CTS and considered as a risk factor.

Most studies dealing with the influence of personal, psychosocial and organizational risk factors of CTS are cross-sectional. Few studies have precisely assessed both psychosocial and physical exposure at work, and both are potentially confounding factors [11]. Therefore, we simultaneously considered the personal, physical and psychosocial risk factors of CTS in workers exposed to repetitive work at a large modern footwear factory. Exposure assessment was performed using both objective and subjective methods in order to take into account the subjective nature of psychosocial factors [13]. The aim of the study was to assess the prevalence and incidence of CTS in the factory workers and to determine the relative contributions of physical and psychosocial factors to the development of CTS in a population with a high level of exposure to repetitive work.

MATERIALS AND METHODS

Subjects

The study was a one year follow-up of workers employed in six production units of a large, modern mechanized footwear factory. Twenty percent of workers were randomly selected among 1250 blue-collar workers for each production unit using the payroll rosters. Of the 253 eligible workers, 199 agreed to participate (79%) in the 1996 study. All participants underwent a physical examination and completed a questionnaire on psychosocial and ergonomic factors between January and December 1996. The main jobs performed were sewing preparation, including cutting (24%), sewing (25%), mechanized (18%) and manual assembly (15%), finishing and packing (18%). Only five of the six production units were included in the study in 1997, because of the decrease in activity of one production unit due to the economic crisis in the footwear industry. Moreover, about 10% of the workers refused to participate in the follow-up study. For these reasons, only 162 workers were followed up and re-examined between January and December 1997. The interval between both examinations was about 12 (11–13) months for all workers (Table 1).

Definition of health outcomes

All the workers were interviewed and examined by the same occupational physician of the company, who was experienced in assessment of WMSDs. Examinations took place at the plant during the twelve-month period using

Table 1. Characteristics of the study groups in 1996 and 1997

	1996	1997
Production units	5	5
Total number of workers	199	162
Females*	122 (61%)	117 (61%)
Age (yr)**	40.7 ± 7.7	41.1 ± 7.0
BMI (kg/m^2)**	24.1 ± 4.2	24.0 ± 4.0
Duration of employment in the factory (yr)**	20.3 ± 4.4	21.2 ± 4.3
Employment at the same workpost (yr)**	15.3 ± 9.6	17.2 ± 9.7
Prevalent cases of CTS	33	34
New cases of CTS	–	19
Free from CTS	166	134

the same procedure. Each worker was asked about pain and symptoms (tingling, burning, numbness, stiffness, lack of mobility, etc.) in one or both of the upper limbs and hands during the previous 12 months and the previous week. The minimal examination procedure consisted of testing the mobility and the sensitivity to pressure of the neck, shoulders, elbows and wrists. Then sensitivity evaluation and provocation tests of CTS were performed. The diagnosis of CTS required (1) the presence of paresthesia, pain or numbness affecting at least part of the median nerve distribution of the hand(s) (i.e., palmar side of the thumb, index finger, middle finger and half radial side of the ring finger; and dorsal side of the same digits above the proximal interphalangeal joint) occurring for at least one week or, if intermittent, occurring at least 10 times during the previous 12-month period; (2) the presence of objective findings in affected hand(s) or wrist(s), including Tinel's sign or positive Phalen's test or diminished or absent sensation to pin prick in the median nerve distribution; and (3) the absence of any sign of other causes of hand numbness or paresthesia such as cervical radiculopathy, thoracic outlet syndrome and pronator teres syndrome.

A case of CTS was defined per worker and not per hand. For workers suffering from pain or symptoms in one of the regions of the upper limb, the physical examination was extended to include specific testing for tension neck syndrome, thoracic outlet syndrome, shoulder tendinitis, lateral and medial epicondylitis and hand/wrist tendinitis [14].

After examination, all workers replied to a self-administered questionnaire including questions about musculoskeletal symptoms, prior medical history, health status, personal and psychological factors, life style and physical activities in spare time. Psychological status was assessed by the French version of the 12-item general health questionnaire (GHQ-12) [15], which has been validated in French [16]. The GHQ-12 has a 4-point scale corresponding to symptoms observed "not at all, same as usual, rather more than usual, much more than usual". The score was calculated with Likert scale (0–1–2–3), resulting in a possible total score of 36, with higher scores representing higher levels of psychological distress [15].

Exposure measurements

Exposure was assessed both by the self-administered questionnaire and standardized workpost analysis for each worker. The work situations of the six plants were classified into twelve groups (e.g. cutting, sewing, pasting, mechanized assembly) according to studies previously performed in the French footwear industry [17].

Self-assessment of exposure. Physical strain and ergonomic factors (force level, repetition level, motion velocity, work postures, local mechanical stress, visual demand, ability to take breaks, job rotation) were self-assessed using a 6-point scale ranging from very low to very high for each factor. Psychological and social aspects of the work situations were only self-assessed. Questions about control on the job (four questions about the possibility of self organization, responsibility at work, clarity of work, availability of means to ensure good quality of work), psychological demand (nine questions about permanent work overload, vigilance strain, permanent tensions, permanent time pressure, possibility of changing movements, possibility of taking breaks, frequency of disruption of work, intensity of work performance control, possibility of forgetting about work at home) and social support (four questions about merits recognized by superiors or not, quality of relationships with colleagues and superiors, quality of the social climate at work) were selected from a validated French questionnaire [18]. The 6-point scale was dichotomized for statistical analysis with the two higher levels considered as positive. Three scores were then calculated: decision latitude score (sum out of 4), psychological work demand score (sum out of 9) and social support score (sum out of 4).

Workpost analysis. The analysis was performed for each worker by direct observation and questioning by two specially trained interviewers using a checklist [19]. When the workers performed two or more jobs, the analysis focused on the most frequent one. The risk factors were: repetitiveness (work cycle <30 sec or >1/2 cycle spent repeating the same motions), force (carrying an object weighing >4.5 kg, holding an object weighing >2.7 or 1 kg per hand), mechanical contact stress and posture (pinch grip, wrist flexion, extension and ulnar deviation). The response modality was dichotomous for the risk factor "repetitiveness" and "local mechanical stress". Ergonomic factors regarding force, posture, equipment and tools had to be present for more than a third of the working cycle to be considered as "positive". Ergonomic scores were calculated for each job performance for right, left and both hands as the sum of "positive" risk factors.

Statistical analysis

The prevalence of CTS in 1996 was calculated as the annual number of registered cases, divided by the total number of workers examined during this year. The incidence rate (IR) in 1997 was calculated as the number of CTS cases occurring in 1997 divided by the total number of workers free from CTS in 1996. All potential risk factors were assessed at baseline. The relationships between the incidence of CTS and potential risk factors were first studied with chi-square tests, exact Fisher's test and one-way analysis of variance (ANOVA) among workers free from CTS in 1996. Ods ratios (OR) were then estimated with backward stepwise logistic regression analysis. All the variables associated with the incidence of CTS with p = 0.15 or less in the bivariate analysis were included in the model [20]. Age (<40, 40–50, >50 years), gender and occurrence of another WMSD in 1996 were forced into the model because of their potential confounding effects. The significance of the variables in the logistic model was assessed with the likelihood ratio test. At each step, insignificant terms ($p > 0.15$) were removed. Therefore, the final model included the variables associated with cases of CTS occurring in 1997 at the last step ($p < 0.15$). All statistical analyses were performed with the SPSS statistical package (SPSS version 10.0).

RESULTS

The populations surveyed in 1996 and 1997 did not differ with regard to gender, years of employment and types of jobs performed. The duration of employment was very long for the majority of the workers (Table 1). Most of the 37 workers who dropped out in 1997 had been transferred to tasks other than footwear production due to the economic crisis. These workers were slightly younger than those followed-up (39.0 ± 5.6 years vs 41.4 ± 7.0 years; p = 0.05). The years at the company and the types of jobs performed maintained similar for all workers whether followed-up or not. Loss to follow-up was significantly associated with higher ergonomic scores (9.2 ± 2.3 vs 8.0 ± 2.4; p = 0.01).

Thirty-three cases of CTS were diagnosed in 1996, i.e. the prevalence at baseline ($PR_{(1996)}$) of 16.6% (95%CI: 11.4-21.7). Fifteen of these cases had a positive diagnosis in 1997 and 10 had recovered. Thirty four cases were diagnosed in 1997. Of these, 19 new cases of CTS were diagnosed in 134 workers free from CTS in 1996, i.e. $IR_{(1997)}$ of 11.7% (95%CI: 6.7–16.8). The clinical features of 19 new cases of CTS are described in Table 2. The new cases of CTS affected right (42%), left (21%), or both hands (37%), and were associated with one pre-existing WMSD at baseline in three cases, while being free from CTS at baseline. CTS cases were associated with one or two new WMSDs in 1997 in 5 cases (26%) (epicondylitis in 2 cases, cubital tunnel syndrome in 1 case, shoulder tendinitis in 1 case, De Quervain disease in 1 case).

On univariate analysis, female gender (Table 3) was not associated with CTS (52% vs 59%; p = 0.623). Age was not significantly different for workers with or without CTS (42.0 ± 8.0 years vs 41.0 ± 7.0 years; p = 0.602). No co-morbidity such as thyroid dysfunction, diabetes mellitus or gynecological disease was associated with new cases of CTS. Parity did not differ between women with and without CTS (p = 0.86). The mean body mass index (BMI) did not differ between workers with or without CTS (24.9 ± 4.6 kg/m^2 vs 24.0 ± 4.0 kg/m^2; p = 0.36). However, obesity (BMI > 30 kg/m^2) at baseline was more frequent for new cases of CTS (26% vs 7%; p = 0.008). Current smoking at baseline was not predictive of CTS (11% vs. 21%; p = 0.37) and neither was the occurrence of co-existing WMSD at baseline (p = 0.94).

The mean GHQ-12 score was over 14 (range 0 to 27), indicating at least mild psychological distress in 32.8% of workers, and it did not differ between workers with or without incident CTS (12.3 ± 7.4 vs 11.9 ± 5.4; p = 0.79). Abnormal GHQ-score (over 14) was not more frequent in

Table 2. Clinical findings and jobs performed by workers with CTS

Case number	Gender, age (yr)	Hand dominance	Paresthesia*	Dystesthesia*	Numbness*	Hypoesthesia*	Thumb paresis	Phalen's sign	Tinel's sign	CTS	Co-existing WMSDs	Yr in company	Yr at workpost	Workpost
1	F,33	R	L	L	L	-		-	L	L	-	15	15	Sewing
2	M,53	R	B	B	B	-		B	B	B	-	30	3	Carding
3	M,39	R	R	-	-	-		R	R	R	-	21	16	Mechanized assembly
4	M,51	R	B	R	B	-	R	R	R	R	-	30	16	Finishing
5**	F,45	R	B	-	-	-		B	R	B	Cub,B	27	27	Pasting
6**	M,48	R	B	-	B	-		B	B	B	ST,R	28	28	Cutting
7	M,44	R	R	R	R	-		R	R	R	-	26	26	Mechanized assembly
8	F,46	R	B	R	R	-		R	R	R	-	26	26	Finishing
9	F,46	R	B	L	L	-	L	L	L	L	-	28	28	Sewing preparation
10	M,50	R	L	-	L	-		L	L	L	-	29	29	Cutting
11	F,42	R	B	B	B	-		-	L	L	-	24	17	Finishing
12	F,54	R	R	R	-	-		R	R	R	-	33	33	Sewing
13	M,25	R	B	-	-	-		R	B	B	-	6	6	Mechanized assembly
14	F,44	R	B	B	B	-	L	L	B	B	-	26	1	Sewing
15**	F,33	R	B	B	B	-		B	R	B	FT,L	15	15	Finishing
16	M,44	R	B	-	-	-		R	R	R	-	18	18	Carding
17	F,36	R	R	-	R	-		R	R	R	-	16	16	Sewing
18	F,31	R	B	L	L	L	L	B	R	B	-	13	13	Sewing
19	M, 34	L	R	-	R	-		-	R	R	-	19	4	Mechanized assembly

F – female; M – male; R – right; L – left; B – bilateral; ST – shoulder tendinitis; Cub – ulnar tunnel syndrome; FT – flexor digitorum tendinitis.
* In at least one of the first three digits.
** The cases of CTS associated with co-existing WMSDs at baseline.

workers with CTS (37% vs 32%; $p = 0.79$). However, GHQ-12 score over the 90th percentile (i.e. over 18.5), which indicates high psychological distress, was more frequent in workers with CTS (21% vs 8%; $p = 0.09$). Use of anxiety-relieving drugs was not predictive of CTS ($p = 0.47$).

With regard to non-occupational exposure, mean duration of weekly household chores was not significantly different between workers with or without CTS (3.4 ± 4.4 h vs 4.9 ± 5.6 h; $p = 0.26$). No association was found between CTS and sports or leisure activities.

Workpost analysis to assess potential risk factors (Table 4) revealed that most of the workers remained in the same workpost for many years, and only one had changed the workpost in 1997. No specific type of job, such as sewing or footwear assembly, was associated with CTS. Physical workload was high for most of the workers since 93% of them were exposed to high repetitiveness (work cycle < 30 sec and/or > 1/2 cycle spent repeating the same motions). However, the force level was below 2.7 kg and even 1 kg for all workers. All the workers were exposed to at least one of the risk factors studied by the checklist. Mean bilateral ergonomic scores were not significantly different between subjects with or without CTS (8.3 ± 2.2 vs. 8.1 ± 2.4; $p = 0.65$). Rapid trigger movements of the finger were most frequent in workers with CTS (21% vs 9%; $p = 0.11$).

Of the self-assessed potential physical risk factors (Table 5), high physical workload, high force level, high movement repetitiveness and velocity were not predictive of

Table 3. Unadjusted odds ratios (OR) for personal factors at baseline. Total number of workers = 134

Personal factors	CTS, 1997			
	Cases (%)	Non cases (%)	OR	95% CI
Female gender	52	59	0.8	(0.3–2.0)
Age				
< 40 yr)	37	37	–	
40–49	42	51	0.7	(0.2–2.0)
≥ 50	21	11	2.1	(0.5–8.2)
BMI > 27 kg/m^2	26	14	2.2	(0.6–8.5)
BMI > 30 kg/m^2	26	7	4.8	(1.2–19.4)*
Daily use of prescribed psychoactive drugs	1	2	0.3	(0.0-2.8)
Use of oral contraceptive	47	49	1.0	(0.3-2.8)
Current smokers	11	21	0.5	(0.1-2.2)
GHQ-12 score ≥ 14/36	37	32	1.2	(0.4-3.7)
GHQ-12 score ≥ 90 percentile (18/36)	21	8	3.1	(0.7-9.3)

*$p \leq 0.05$

CTS. With regard to self-assessed psychosocial factors, perceived high psychological and visual workloads were not predictive of CTS. The incidence of CTS was associated with the lack of possibility to take breaks ($p = 0.07$), which is indicative of low autonomy at work. Unexpectedly, strong control of the work performance by superiors was less frequent in workers with CTS (37% vs 57%; $p = 0.11$). Psychologically demanding work score did not differ between workers with or without CTS (4.7 ± 1.8 vs 4.6 ± 1.7; $p = 0.79$). Decision latitude score (1.7 ± 1.2 vs 2.0 ± 1.3; $p = 0.35$) and social support score (2.0 ± 1.2 vs 2.2 ± 1.3; $p = 0.40$) were not significantly different between workers with and without CTS.

The cases of CTS were categorized according to the presence or absence of co-existing WMSDs at baseline. Age, BMI and GHQ-12 score did not differ between the groups. Past medical history and non-occupational activities were similar for both groups. However, duration of employment

Table 4. Unadjusted odds ratios (OR) for the ergonomic risk factors assessed by workpost analysis at baseline. Total number of workers =134

Objective workload assessment	CTS, 1997			
	Cases (%)	Non cases (%)	OR	95% CI
No job rotation between different workpost	21	34	0.5	(0.1–1.8)
Work cycle time < 30 sec	68	76	0.7	(0.2–2.3)
Similar movement pattern for more than 50% of work time	84	85	0.9	(0.2–4.8)
Wrist deviation	37	37	1.0	(0.4–3.1)
Rapid trigger movements	21	9	2.8	(0.6–11.5)
Vibration transmitted to the hand	11	6	1.8	(0.2–10.8)
Wrist flexion > 45°	11	16	0.6	(0.1–3.2)
Wrist extension > 45°	42	39	1.2	(0.4–3.4)
Left hand ergonomic score over 4	53	67	0.6	(0.2–1.6)
Right hand ergonomic score over 4	63	67	0.8	(0.3–2.6)
Both hands ergonomic score over 8	58	63	0.8	(0.3–2.4)

Table 5. Unadjusted odds ratios (OR) of the self-assessed physical and psychosocial risk factors. Total number of workers = 134

Subjective workload assessment	CTS, 1997			
	Cases(%)	Non cases (%)	OR	95% CI
Perceived high physical workload	26	37	0.6	(0.2–2.0)
Perceived high psychological workload	37	37	1.0	(0.3–3.1)
Perceived high force level	32	30	1.1	(0.3–3.3)
High movement precision	53	50	1.4	(0.5–4.1)
High visual load	68	66	1.1	(0.4–3.6)
Permanent tension during work	37	30	.3	(0.4–4.1)
Permanent time pressure	37	30	1.3	(0.4–4.1)
Lack of freedom to change movements when desired	84	67	2.4	(0.6–11.2)
Few possibilities to take breaks	68	46	2.5	(0.8–8.1)*
Work strongly controlled by superiors	37	57	0.5	(0.2–1.3)
Lack of job clarity	42	47	0.8	(0.3–2.3)
High work demand score[a]	32	22	1.7	(0.5–5.4)
Low score for task control[b]	42	36	1.3	(0.4–3.8)
Low score for social support[c]	42	32	1.6	(0.5–4.9)

[a] Total score for nine questions about permanent work overload, vigilance strain, permanent tensions, permanent time pressure, possibility of changing movements, possibility of taking breaks, frequency of disruptions at work, intensity of control of the work performed, possibility of forgetting work at home.
[b] Total score of four questions about possibility of self organization, responsibility at work, clarity of work, having the means to do good quality work.
[c] Total score of four questions about recognition of merit by the superiors or not; quality of relationships with colleagues and with superiors, quality of social climate at work.
* $p \geq 0.05$–0.10.

at the same workpost was longer in cases of associated WMSDs at baseline (24.0 ± 7.2 years vs 14.9 ± 9.4 years). No differences were observed for ergonomic scores or job characteristics such as physical or psychological workload. Out of the potential determinants of CTS, two were associated with CTS in the logistic model (Table 6) with p-level below 0.05. Obesity was associated with high risk of CTS occurrence (OR = 4.4 (95%CI: 1.1–17.1); p = 0.033). Psychological distress at baseline assessed by a very high GHQ-12 score (over the 90th percentile) was strongly predictive of CTS (OR = 4.3 (95%CI: 1.0–18.6); p = 0.049). Two other factors remained in the model with p-value below 0.15. Performance of rapid trigger movements of the finger with hand tools was predictive of CTS (OR = 3.8 (95%CI: 1.0–17.2); p = 0.058). However, high hierarchical control of the work performed was negatively associated with CTS (OR = 0.5 (95%CI: 0.2–1.3); p = 0.039).

Table 6. Risk factors for new cases of CTS in 1997, according to the logistic model. Number of cases = 19 out of 134 workers

Factors	OR	95% CI	P-value[a]
BMI > 30 kg/m^2	4.4	(1.1–17.1)	0.033
GHQ-12 score > 90th percentile	4.3	(1.0–18.6)	0.049
Rapid trigger movements	3.8	(1.0–17.2)	0.058
Work strongly controled by superiors	0.5	(0.2–1.3)	0.139

Variables included in the model were not significantly associated with new CTS cases: age (<30; 30–40; >40 years), female gender, limited possibility to take breaks.
[a] -2 LR = 95.866, degree of freedom = 4, $X^2 = 13.225$, p = 0.010.

DISCUSSION

This study examined a wide range of potential risk factors because any single behavior or characteristics seem to be indispensable and sufficient to cause CTS [21]. Risk factors were assessed before the onset of CTS, allowing the assessment of etiological risk factors [8]. The workers' turnover was low because they attempted to organize themselves to keep up with the daily demands of the job, despite frequent hand symptoms. Stability of the work force is valuable in conducting a follow-up study. Few workers dropped out from the study mainly due to economic reasons. The prevalence of CTS and other WMSDs in the drop-out-group in 1996 did not differ from the remaining group, and therefore those lost to follow-up probably had a low impact on the risk estimate. The main limitation of the study was the small number of CTS cases, which was due to the high level of the disorder prevalence and a small size of the sample studied. All associations should therefore be interpreted with caution.

The definition of CTS corresponded to the clinical criteria of the NIOSH definition [22]. Misclassification of case status may have occurred, as Tinel's and Phalen's signs have been reported to have limited sensitivity and specificity [22]. According to the NIOSH definition of CTS, neurophysiological studies were not systematic. The choice of this definition of the outcomes, which disagrees with a recent consensus requiring nerve conduction studies [23], is explained by the lack of available conduction nerve device in the occupational setting. However, the definition is in agreement with a recent consensus [24], for which typical symptoms combined with one clinical finding were considered sufficient for the diagnosis of CTS.

Most of the workers had the same year to year work constraints because of the few changes in the technical processes in the footwear factory. In particular, exposure of the subjects who changed from non-case to case during the follow-up period had obviously not changed over time. Most of the workers suffering from one WMSD in 1996 remained at the same workpost during the follow-up period. This was not due to successful treatment, but to the fact that it was impossible to offer patients less stressful jobs in the company [25]. One feature of the study was the combination of objective and subjective methods to provide appropriate evaluation of the complete individual job exposure [26]. Objective assessment by direct observation, using a checklist allows sensitive evaluation of the main physical ergonomic stressors [19], while subjective assessment takes into consideration the worker's perception of the work strain. The self-questionnaire on the physical load had previously been validated in France [18]. Psychological demands and factors related to work organization were self-assessed because of their subjective nature [13]. Psychological problems were assessed by GHQ-12, which is the most widely used screening instrument for common mental disorders [27]. Its brevity makes it attractive for use in occupational settings, although it cannot be employed for diagnostic purposes. Likert scoring has been validated and provides similar screening properties to conventional scoring [28].

Both the prevalence and incidence of CTS were high in the whole factory because of the high level of ergonomic strains, according to previous studies in the footwear industry [6,17,29]. The incidence was much higher than in the general population [1–3] and numerous industries and activities [2,4]. The incidence rate of CTS was higher than WC claims records for the footwear industry, which confirms that WC records underestimate the incidence of WMSDs [30]. However, it was similar to that in a modern meat processing plant (i.e. 11 cases per 100 person-years) [31], and higher than that observed in a panel of eighteen French factories, for which a 3-year incidence of CTS was about 12% [32].

In a study that simultaneously assessed the role of a broad range of putative CTS risk factors, we found associations between CTS and four personal and occupational factors. The study demonstrates a strong association between CTS and psychological distress at baseline. The mean score observed in the whole sample (about 12/36) was similar to that observed in 3000 persons aged between 16 and 64 years in the general population [33]. The cut-off point of the GHQ score at 14/36 allows the best ratio between sensitivity and specificity [28]. A higher threshold, corresponding to the 90th percentile (i.e., 18.5/36), was also chosen to provide a high positive predictive value [28]. The GHQ score of the workers may have been relatively high because the GHQ includes not only symptoms of anxiety and depression but also of mild psychiatric symptoms [34]. However, the scores observed in the present study agree with the results of a previous study conducted in the footwear industry using Langner's screening questionnaire [17]. Of the 1778 workers studied, 8.5% had a score over 8, which indicates mild to severe psychological distress, and 12.3% had a score from 5 to 7, which suggests slight to mild psychological distress. Due to the prospective nature of the study, the results demonstrate that high psychological distress is a cause rather than a consequence of CTS. Psychological distress has more often been found to be predictive of low-back pain and neck-shoulder disorders [35,36] than of CTS. Psychological distress can change the workers' estimation of illness and pain [13]. However, as the diagnosis of CTS relied not only on symptoms but also on physical examination, the change in the perception of pain probably played a minor role in the diagnostic process. It has been speculated that psychosocial factors may induce physiological changes that might result in musculoskeletal disorders [11]. However, the mechanisms remain unclear and are probably different for musculoskeletal disorders of the proximal and distal parts of the upper limb [11,13,37]. This study cannot explain the causes of psychological distress, which may be not only due to personal psychological characteristics and private life but also to working conditions other than psychosocial work factors already taken into account in the model [12].

This study confirms that obesity is predictive of CTS, which agrees with the results of studies [32] conducted in the general [9,38] and industrial populations [12,32,39]. The percentage of co-morbid conditions was very small (i.e. thyroid dysfunction in one case and menopause in one case) in comparison with findings in the general population [1,40], which agrees with other studies conducted in the working population [10,12].

The logistic model highlights the use of rapid trigger movements with the finger as a risk factor for CTS. Rapid finger trigger movements required to activate electric tools such as screw drivers and cutters increased the risk of CTS in this study. Trigger finger movements with tools have more often been associated with tenoynovitis of the flexor tendons (trigger finger) [19] than with CTS. No other biomechanical risk factors were identified in the factory. This could be due to a lack of statistical power in the study. Work organization may affect the level of job stress and mental strain experienced by workers through various stressors [41]. The psychological demand was high for most workers, while monotonous work, time pressure and perceived high workload were not related to CTS. Strong control over the work by superiors was associated with CTS in an unexpected way. Control of the work performance by superiors increases psychological demand, which is expected to increase the level of work stress and thus the occurrence of musculoskeletal problems [11,13,37]. However, such high level of supervision may be interpreted by workers as recognition of the quality of the work performed and, consequently, as recognition of their personal merit by their superiors, which is known to diminish psychological strain [42]. Work organization in the footwear factory does not encourage workers to take breaks whenever they are needed or to change their movements. This rigid structure of tasks creates conditions in which workers are overworked [41], according to the "job demand – decision latitude" model [11,13,43]. However, no clear relationship was found between the incidence of CTS, psychological demands and lack of social support.

CONCLUSION

The prevalence and incidence of CTS in this workforce were substantially higher than in the general population and numerous industries. The study emphasizes the multifactorial nature of CTS, since personal factors and exposure to physical and psychosocial stressors at work independently affect the incidence of CTS. Psychosocial factors play a major role in the factory studied, which exposes its workers to a high level of physical load. In particular, high psychological distress seems to be a cause rather than a consequence of CTS.

ACKNOWLEDGEMENTS

We wish to thank Ms Annette Leclerc (Inserm U 88, Saint-Maurice, France) for her valuable comments on the manuscript.

REFERENCE

1. Stevens JC, Beard CM, O'Fallon WM, Kurland LT. *Conditions associated with carpal tunnel syndrome.* Mayo Clin Proc 1992; 67: 541–8.
2. Rossignol M, Stock S, Patry L, Armstrong B. *Carpal tunnel syndrome: what is attributable to work? The Montreal Study*. Occup Environ Med 1997; 54: 519–23.
3. Nordstrom DL, DeStefano F, Vierkaut RA, Layde PM. *Incidence of diagnosed carpal tunnel syndrome in a general population.* Epidemiology 1998; 9: 342–5.
4. Hagberg M, Morgenstern H, Kelsh M. I*mpact of occupations and job tasks on the prevalence of carpal tunnel syndrome*. Scand J Work Environ Health 1992; 18: 337–45.
5. Bernard B. *Musculoskeletal disorders and workplace factors. A critical review of epidemiological evidence for work-related musculoskeletal disorders of the neck, upper-extremity, and low back.* Cincinnati: DHHS (NIOSH); 1997. p. 97–141.
6. Andersen JH, Gaardboe O. *Prevalence of persistent neck and upper limb pain in a historical cohort of sewing machine operators*. Am J Ind Med 1993; 24: 677–87.
7. Brisson C, Vinet A, Vezina M. *Disability among female garment workers*. Scand J Work Environ Health 1989; 15: 323–8.
8. Kaergaard A, Andersen JH. *Musculoskeletal disorders of the neck and shoulders in female sewing machine operators: prevalence, incidence, and prognosis.* Occup Environ Med 2000; 57: 528–34.
9. Vessey MP, Villard-Mackintosh L, Yeates D. *Epidemiology of carpal tunnel syndrome in women of childbearing age. Findings in a large cohort study.* Int J Epidemiol 1990; 19: 655–9.
10. Viikari-Juntura E, Silverstein B. *Role of physical load factors in carpal tunnel syndrome*. Scand J Work Environ Health 1999; 25: 163–85.
11. Bongers PM, de Winter CR, Kompier MAJ, Hildebrandt VH. *Psychosocial factors at work and musculoskeletal disease.* Scand J Work Environ Health 1993; 19: 297–312.
12. Leclerc A, Franchi P, Cristofari MF, Delemotte B, Mereau P, Teyssier-Cotte C, et al. *Carpal tunnel syndrome and work organization in repetitive work: a cross sectional study in France.* Occup Environ Med 1998; 55: 180–7.
13. Theorell T, Harms-Ringdahl K, Ahlberg-Hunten G, Westin B. *Psychosocial job factors and symptoms from the locomotor system – a multicausal analysis.* Scand J Rehab Med 1991; 23: 165–73.
14. Pujol M. *Overuse occupational diseases. Musculoskeletal disorders of the upper limbs. Textbook of occupational medicine.* Paris: Masson; 1993. p.19–125 [in French].
15. Goldberg D, Gater R, Sartorius N, Ustun TB, Piccinelli M, Gureje O, et al. *The validity of two versions of the GHQ in the WHO study of mental illness in general health care.* Psychol Med 1997; 27: 191–7.
16. Pariente P, Guelfi JD. *Self-assessment of psychological status in adults. I. Multidimensional scale.* Psychiat Psychobiol 1990; 5: 87–102 [in French].
17. Roquelaure Y, Touranchet A, Mandereau L, Fanello S, Hémon D, Penneau-Fontbonne D. *Workers' health status in the footwear industry of the Pays de la Loire region.* Arch Mal Prof 1994; 55: 441–7 [in French].
18. Cail F, Aptel M. *Upper limb musculoskeletal disorders.* Paris: INRS; 1996. p. 1–64 [in French].
19. Keyserling WM, Stetson DS, Silverstein BA, Brouwer ML. *A check list for evaluating risk factors associated with upper extremity cumulative trauma disorders.* Ergonomics 1993; 36: 807–31.
20. Bouyer J, Hémon D, Cordier S, Derriennic F, Stűcker I, Stengel B, et al. *Epidemiology. Principles and methods.* Paris: INSERM; 1995. pp. 498 [in French].
21. Hagberg M, Silverstein B, Wells R, Smith MJ, Hendrick HW, Carayon P, et al. *Work related musculoskeletal disorders (WMSDs): a reference book for prevention.* Kuorinka I., Forcier L., editors. London: Taylor and Francis; 1995. pp. 421.
22. Katz JN, Larson MG, Fossel HH, Liang MH. *Validation of a surveillance case definition of carpal tunnel syndrome.* Am J Public Health 1991; 81: 189–93.
23. Rempel D, Evanoff B, Amadio PC, de Krom M, Franklin G, Franzblau A, et al. *Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies*. Am J Public Health 1998; 88: 1447–51.
24. Harrington JM, Carter JT, Birrell L, Gompertz D. *Surveillance case definitions for work-related upper limb pain syndromes.* Occup Env Med 1998; 55: 264–71.
25. Roquelaure Y, Méchali S, Dano C, Fanello S, Benetti F, Bureau D, et al. *Occupational and personal risk factors for carpal tunnel syndrome in industrial workers.* Scand J Work Environ Health 1997; 23: 364–9.
26. Winkel J. *Exposure assessment in ergonomic epidemiology and intervention studies.* 25th International Congress on Occupational Health; 1996 Sep 15–20; Stockholm, Sweden. Solna: National Institute for Working Life; 1996, pp. 40 [Book of abstracts].
27. Wernecke U, Goldberg DP, Yakcin I, Üstün T. *The stability of the factor structure of the General Health Questionnaire*. Psychol Med 2000; 30: 823–9.

28. Piccinelli M, Bisoffi G, Bon MG, Cunino L, Tansella M. *Validity and test-retest of the Italian version of 12-item general health questionnaire in general practice: a comparison between three scoring methods*. Compr Psychiatry 1993; 34: 198–205.
29. Schibye B, Skov T, Ekner D, Christianssen JU, Sjøgaard G. *Musculoskeletal symptoms among sewing machine operators*. Scand J Work Environ Health 1995; 21: 427–34.
30. Silverstein BA, Stetson S, Keyserling MW, Fine LB. *Work related disorders: comparison of data sources for surveillance.* Am J Indust Med 1997; 31: 600–8.
31. Gorsche RG, Wiley P, Renger RF, Brant RF, Gemer TY, Saysyniuk TM. *Prevalence and incidence of carpal tunnel syndrome in a meat packing plant*. Occup Environ Med, 1999; 56: 417–22.
32. Leclerc A, Landre MF, Chastang JF, Niedhammer I, Roquelaure Y. *A longitudinal study on upper limb disorders in repetitive work.* Scand J Work Environ Health 2001; 27: 268–78.
33. McCabe CJ, Thomas KJ, Brazier JE, Coleman P. *Measuring the mental health status of a population: a comparison of the GHQ-12 and the SF-36 (MHI-5).* Br J Psychiat 196; 169: 517–21.
34. Shigemi J, Miw Y, Ohtsu TTT, Tsuda T. *Effects of perceived job stress on mental health. A longitudinal survey in a Japanese electronics company.* Eur J Epidemiol 2000; 16: 371–6.
35. Leino P, Magni G. *Depressive and distress symptoms as predictors of low back pain, and other musculoskeletal morbidity: a 10-year follow-up o metal industry employees.* Pain 1993; 53: 89–94.
36. Manninen P, Heliovaara M., Rihimaki H, Makela R. *Does psychological distress predict disability?* Int J Epidemiol 1997; 26: 1063–70.
37. Toomingas A, Theorell T, Michelsen H, Nordemar R. *Associations between self-rated psychosocial work conditions and musculoskeletal symptoms and signs.* Scand J Work Environ Health 1997; 23: 130–9.
38. Nordstrom DL, Vierkaut RA, DeStefano F, Layde PM. *Risk factor for carpal tunnel syndrome in a general population.* Occup Environ Med 1997; 54: 734–40.
39. Nathan PA, Keniston RC. *Carpal tunnel syndrome and its relation to general physical condition*. Hand Clin 1993; 9: 253–61.
40. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. *Prevalence of carpal tunnel syndrome in a general population.* JAMA 1999; 282: 153–8.
41. Smith MJ, Sainfort PC. *A balance theory of job design for stress reduction*. Int J Indust Erg 1989; 4: 67–79.
42. Dejours C. *Work and mental worn out. Essay on work psychopathology.* Paris: Bayard; 1993. p. 1–263 [in French].
43. Karasek RA. *Job demands, job decision latitude, and mental strain: implications for job redesign.* Admin Sci Quart 1979; 24: 285–311.

Received for publication: August 20, 2001
Approved for publication: October 30, 2001