



Original article

Scand J Work Environ Health 2001;27(4):268-278

doi:10.5271/sjweh.614

Upper-limb disorders in repetitive work

by [Leclerc A](#), [Landre M-F](#), [Chastang J-F](#), [Niedhammer I](#), [Roquelaure Y](#);
Study Group on Repetitive Work, the

Affiliation: INSERM Unité 88, Hôpital National de Saint-Maurice, 14 rue du val d'Osne, F-94415 Saint-Maurice CEDEX, France.
a.leclerc@st-aurice.inserm.fr

Refers to the following texts of the Journal: [1999;25\(3\):163-185](#)
[1995;21\(6\):478-486](#) [1995;21\(2\):134-142](#) [1995;21\(6\):427-434](#)

The following articles refer to this text: [2003;29\(5\):354-362](#);
[2004;30\(3\):234-240](#); [2007;33\(1\):58-65](#); [2009;35\(5\):342-348](#);
[2011;37\(2\):85-98](#); [2011;37\(4\):298-306](#); [2011;37\(6\):455-463](#);
[2014;40\(6\):610-620](#)

Key terms: [carpal tunnel syndrome](#); [epicondylitis](#); [longitudinal study](#);
[psychosocial factor](#); [repetitive work](#); [upper-limb disorder](#); [work characteristic](#); [wrist tendinitis](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/11560341



This work is licensed under a [Creative Commons Attribution 4.0 International License](http://creativecommons.org/licenses/by/4.0/).

Upper-limb disorders in repetitive work

by Annette Leclerc, PhD,¹ Marie-France Landre, MSc,¹ Jean-François Chastang, PhD,¹ Isabelle Niedhammer, PhD,¹ Yves Roquelaure, PhD,² the Study Group on Repetitive Work

Leclerc A, Landre M-F, Chastang J-F, Niedhammer I, Roquelaure Y, the Study group on Repetitive Work. Upper limb disorders in repetitive work. *Scand J Work Environ Health* 2001;27(4):268—278.

Objectives A longitudinal study was conducted to determine the predictability of personal and occupational factors with respect to the incidence of upper-limb disorders in occupations requiring repetitive work.

Methods A sample of 598 workers in five activity sectors completed a self-administered questionnaire; the workers were examined by an occupational health physician in 1993—1994 and 3 years later. Three disorders were considered, carpal tunnel syndrome (CTS), lateral epicondylitis and wrist tendinitis.

Results The results of this longitudinal study indicated that the following three sets of risk factors independently affect the incidence of upper-limb disorders: (i) biomechanical constraints, (ii) psychosocial factors, and (iii) personal factors. The combination of risk factors differed between CTS, lateral epicondylitis, and wrist tendinitis. The presence of psychosomatic problems was a strong predictor of wrist tendinitis. Social support at work was also associated with the incidence of wrist tendinitis. The presence of depressive symptoms and other upper-limb disorders predicted the first occurrence of lateral epicondylitis. Age was associated only with epicondylitis. The results were consistent with those concerning the role of forceful movements of the elbow for epicondylitis and confirmed the role of forceful movements for CTS.

Conclusions This study considered different sets of risk factors simultaneously with a longitudinal approach, in a population with a high level of occupational exposure. The results indicate that three sets of risk factors independently affect the incidence of upper-limb disorders. In addition to biomechanical constraints, psychosocial and personal factors play a role.

Key terms carpal tunnel syndrome, epicondylitis, longitudinal study, psychosocial factors, work characteristics, wrist tendinitis.

Work-related upper-limb disorders represent an important problem throughout the world, especially in industrialized countries. Several reviews, synthesis articles, reports, and books have recently been devoted to the subject (1—8). They include results from numerous studies on the associations of these disorders with personal and occupational factors, both biomechanical and psychosocial. Knowledge remains sparse in some areas, however. The specific diagnosis that has been studied most is carpal tunnel syndrome (9). Fewer studies have examined epicondylitis (10, 11). Occupational risk factors have been studied hardly at all for less common disorders, such as De Quervain's disease (12).

Another limitation of the studies on this subject is the scarcity of longitudinal studies, especially those that

look at risk factors for the incidence of specific disorders and describe occupational constraints in detail. Models have been proposed to take into account a large range of etiologic factors and mechanisms, but the dimension of time has not been the object of much investigation (13).

A few prospective surveys have studied the natural course of nonspecific disorders (14, 15), the incidence of specific disorders among the general population (16), and the role of occupational factors in morbidity score modification (17, 18). A general review, based on 13 studies, focused on the question of the prognosis and clinical course of nonspecific work-related musculoskeletal disorders of the neck and upper extremities (19).

¹ INSERM (National Institute on Health and Medical Research), Unité 88, Saint Maurice, France.

² Service de pathologie professionnelle, Centre Hospitalo-Universitaire (University Hospital), Angers, France.

Reprint requests to: Dr Annette Leclerc, INSERM Unité 88, Hôpital National de Saint-Maurice, 14 rue du val d'Osne, F-94415 Saint-Maurice CEDEX, France. [E-mail: a.leclerc@st-aurice.inserm.fr]

A small number of longitudinal studies or repeated cross-sectional examinations has been performed in groups of workers at high risk of upper-limb disorders. The main objectives have been to estimate the incidence and improve knowledge of the frequency and natural course of specific disorders or to study the effects of changes in exposure or occupation (20–27). Findings from these studies are not always comparable; for example, the term “incidence” is used with several meanings, including the rate of absenteeism episodes (27).

Longitudinal studies in high-risk sectors have shown links between work conditions and symptom development (24, 26), without providing much detail on the role of occupational risk factors.

Many authors insist that selection effects at the workplace limit the interpretation of results from cross-sectional studies (11, 24, 28). Not enough is known, however, about the extent of health selection effects due to specific disorders in different work environments.

The results presented in this report come from the continuation of a cross-sectional study conducted in 1993–1994 (29–31). Three years later, a subsample of the workers from that study, who were exposed to repetitive work, was included in a follow-up longitudinal study. Our principal objective was to study the predictability of personal and occupational factors with respect to the incidence of upper-limb disorders.

“Incidence” was defined as the risk of occurrence of a specific disorder during the 3-year period among subjects without this disorder at baseline.

We studied the following three categories of upper-limb disorders, assessed in medical examinations during 1993–1994 and 1996–1997: (i) incidence of definite or suspected carpal tunnel syndrome, (ii) incidence of definite or suspected lateral epicondylitis, and (iii) incidence of definite or suspected wrist tendinitis, including three disorders, hand or wrist extensor peritendinitis or tenosynovitis, hand or wrist flexor peritendinitis or tenosynovitis, and De Quervain’s disease.

Subjects and methods

Subjects

In 1993–1994, 1420 workers whose occupations required repetitive work completed a self-administered questionnaire about their work conditions and upper-limb disorders. They also underwent a standardized physical examination by the occupational health physician in charge of the medical surveillance of the workers in their company.

The workers were selected according to occupational criteria. They were required to be exposed to repetitive

work in one of the following five activity sectors: (i) assembly line in the manufacture of small electrical appliances, motor vehicle accessories, or ski accessories (packaging excluded), (ii) clothing and shoe industry (packaging excluded), (iii) food industry (mainly, meat industry), packaging excluded, (iv) packaging (primarily in the food industry), (v) supermarket cashiering.

Four of the subgroups included both genders; all the supermarket cashiers were women.

The 39 occupational health physicians responsible for surveying small groups of workers in the cross-sectional study were asked to repeat the study 3 years later. Six could not conduct a second survey because of major changes in their companies, such as factory closings or drastic layoffs. Twelve were too busy to participate. One no longer surveyed the study population and could not be replaced. Two participated only partially, and more than half their initial subjects were lost to follow-up.

The remaining 18 physicians had examined 700 workers in 18 different firms in 1993–1994. These 700 persons were the target population of the longitudinal study. Of them, 102 (15%) were completely or partly lost to follow-up, including those with one questionnaire (self-administered or medical) missing. Most of those in this group of 102 no longer worked for the same company.

In all, 598 workers completed the self-administered questionnaire and were examined by the physician. Most of these workers had the same (or similar) occupational constraints as 3 years earlier, in the same company. Four of them did not work in the same firm; 134 (22.4%) said that their job or their work station had changed in the period in question. For 36 of them, the change was for medical reasons. Table 1 describes the sample.

Medical variables

Each worker underwent a standardized clinical examination, performed by the occupational health physician at the beginning of the study and again at the end of the follow-up. A list of criteria for the diagnoses recorded in the medical questionnaire was prepared for this survey. These guidelines covered 33 diagnoses at the beginning of the study and 35 at the time of the follow-up, the slight changes between the two lists being limited to shoulder tendinitis.

The list included the following diagnoses and corresponding criteria: (i) carpal tunnel syndrome: Tinel’s sign or Phalen’s test positive (or diagnosis based on nerve conduction velocity, for “proved diagnosis before the medical examination”); (ii) lateral epicondylitis: epicondylar pain or epicondylar tenderness and pain on

Table 1. Description of the sample and the prevalence of upper-limb disorders at the beginning of the study.

	N	Carpal tunnel syndrome ^a		Lateral epicondylitis ^a		Wrist tendinitis ^a	
		Cases (N)	Prevalence (%)	Cases (N)	Prevalence (%)	Cases (N)	Prevalence (%)
Gender							
Male	178	20	11.2	17	9.6	34	19.1
Female	420	111	26.4	56	13.3	33	7.9
Sector							
Assembly	247	54	21.9	50	20.2	21	8.5
Clothing	63	17	27.0	3	4.8	2	3.2
Food	143	19	13.3	10	7.0	30	21.0
Packaging	103	32	31.1	8	7.8	11	10.7
Cashiers	42	9	21.4	2	4.8	3	7.1
Age							
≤ 29 years	117	16	13.7	5	4.3	21	17.9
30-39 years	225	52	23.1	19	8.4	25	11.1
40-49 years	203	51	25.1	35	17.2	14	6.9
≥50 years	53	12	22.6	14	26.4	7	13.2
Whole sample	598	131	21.9	73	12.2	67	11.2

^a Proved or suspected.

resisted extension of the wrist, (iii) hand or wrist extensor peritendinitis or tenosynovitis: pain in the dorsal wrist, swelling of the affected tendons or palpable crepitus of the affected tendons, (iv) hand or wrist flexor peritendinitis or tenosynovitis: pain in the ventral wrist, swelling of the affected tendons, palpable crepitus of the affected tendons, or finger extension and flexion deficits, (v) De Quervain's disease: pain on the radial side of the wrist, tender swelling, or pain produced by thumb extension, thumb abduction or the Finkelstein test. The latter three diagnoses were grouped together as "wrist tendinitis" in this study. A similar grouping has been used in other studies (12, 32, 33).

The following three situations or levels were possible for each of the five diagnoses: (i) proved diagnosis in the medical examination (= Tinel's sign or Phalen's test positive for carpal tunnel syndrome; all criteria met for the other diagnoses), (ii) proved diagnosis before the medical examination (for example, diagnosis made by a specialist), and (iii) suspected diagnosis (not all the criteria met in the medical examination or diagnosis based on the description of symptoms that were no longer present at the time of the examination).

The four most frequent diagnoses were shoulder tendinitis, carpal tunnel syndrome, lateral epicondylitis, and wrist tendinitis. Shoulder tendinitis was not included, since the medical questionnaire and the guideline for this disorder had changed between the two examinations.

We defined disorders extensively (ie, we included both proved and suspected diagnoses) in this study and consequently used a strict definition of "healthy at baseline" as complete absence of the disorder (neither proved nor suspected). This criterion increased the sta-

tistical power since the number of incident cases was larger. For carpal tunnel syndrome, lateral epicondylitis, and wrist tendinitis, the subjects classified as "suspected" at baseline were not included in the study of the incidence of the corresponding disorder. For wrist tendinitis, the subjects taken into account for the study on incidence were those who had none (neither proved nor suspected) of the three disorders that made up the definition of wrist tendinitis.

The incident cases of carpal tunnel syndrome, lateral epicondylitis, and wrist tendinitis included cases with symptoms in the 3-year period between the three questionnaires but with no symptoms at the time of the second examination. These subjects had no symptoms for the corresponding disorder before (or at the time of) the first questionnaire.

The definitions were based exclusively on the results of the medical examination. The answers to the hand diagram in the self-administered questionnaire were not taken into account in order to rely on independent sources of information for the medical condition and for occupational exposure. In addition, the reference period in the self-administered questionnaire was the last 6 months, which was not a reference period in the medical examination.

The list of potential determinants of the incidence of one disorder included the total number of proved or suspected other diagnoses (0, 1, 2, 3 or more) from the list of 33.

Potential risk factors

All three disorders were studied with the same list of potential risk factors, including the total number of other

diagnoses. This list included personal and occupational variables, that is, self-assessment of whether specific postural and biomechanical constraints and psychosocial stresses were present at work.

The list of variables was based on the results from other studies and considered variables known or suspected to be a risk factor for at least one of the three disorders studied. The list was similar to that used in the analyses focusing on prevalence in the cross-sectional study. These variables are summarized under the subheadings that follow.

Personal and occupational variables. The personal and occupational variables included the following:

- Gender
- Age, in four categories (≤ 29 , 30—39, 40—49, ≥ 50 years)
- Occupational variables: activity sector (of the 5 possible) and number of years on the job (< 1 , $1 - < 10$, ≥ 10 years)
- Smoking (nonsmoker, ex-smoker, smoker)
- Body mass index (BMI): overweight, defined as BMI > 27 kg/m² for men and > 26.5 kg/m² for women
- Increase in weight: BMI increased by ≥ 2 kg/m² between the two questionnaires
- Presence of somatic problems: “presence” was defined as a yes answer to at least one of the following questions: do you often have headaches; do you often have sleep disorders; are you often bothered by your heart beating hard; do you have personal worries that get you down physically. (An alternative score without sleep disorders was also used, since sleep disorders can be a consequence of carpal tunnel syndrome.)
- Presence of depressive symptom(s): “presence” was defined as a yes answer to at least one of the following problems: are you in low spirits or very low spirits most of the time; are you often bothered by nervousness; do you often feel that nothing ever turns out the way you want it to; do you sometimes wonder if anything is worthwhile anymore.

Postures and biomechanical constraints. The job duties mentioned in the questionnaire included the following actions: turn and screw, tighten with force, work with force (other than tighten), press with the hand, press with the elbow, hit, pull, push, hold in position. For each of these constraints, two categories were used, repetitively (self-assessed) versus not repetitively or never. The use of vibrating tools was self-assessed (irrespective of frequency).

Psychosocial work factors. Job control (a score from 0 to 8) was calculated as the sum of the following yes or no

items: no choice of the timing of breaks; unscheduled short breaks not possible; pace dictated by the machine, by colleagues, by other constraints; no control over the quantity of work; no control over the pace of the work; lack of variety of work. A low level of job control was defined as a score of ≥ 5 .

For the psychological demand of the job, a high level of demand was defined as positive answers to both of the following relevant questions: are you permanently overloaded with work and do you have periods with increased workload?

With respect to social support at work, lack of social support was defined as a negative answer either about work relations in general or about relations with colleagues.

For satisfaction at work, a low level of satisfaction was defined as a negative answer either about satisfaction with the workstation or about general job satisfaction.

Methods

The relations between the incidence of upper-limb disorders and the risk factors at baseline were studied first with bivariate associations and chi-square tests for the overall population and separately for the men and women. The potential determinants in this part of the analysis were gender, age, activity sector, number of years on the job, smoking, total number of diagnoses given by the occupational physician, BMI, psychological problems (somatic and depressive), work postures and biomechanical constraints, and psychosocial work factors. For BMI we considered that a change in BMI between the two questionnaires was more relevant than the baseline BMI; in addition, the onset of a new disorder may result from a change in BMI, but the opposite (BMI changing as a consequence of the onset of a disorder) is much less likely.

A logistic model was used to study the potential determinants of incidence with BMDP software (34). We used a backward stepwise modeling strategy. The initial variables in the model were those measured in 1993—1994 (plus BMI change). The list was limited to age, gender, and the variables associated with the incidence at a P-level of ≤ 0.15 in the bivariate analysis. At each step, nonsignificant terms ($P > 0.15$) were removed, except age and gender, which were kept in the model. The final model included age, gender, and the variables associated with incidence in the last step ($P < 0.15$). For carpal tunnel syndrome, the determinants of incidence were studied separately for the men and women with logistic models, because bivariate analyses indicated that the determinants differed between the two genders. The final models were run also with a stricter definition for

incident cases — only proved diagnosis — in order to verify that the results were not changed if an alternative definition for cases was adopted.

Factors associated with loss to follow-up

The 102 workers lost to follow-up were compared with the 598 with two complete questionnaires. Loss to follow-up was significantly associated with age and activity sector. It was more frequent in the extreme age categories (those younger than 30 years and at least 50 years of age) and among supermarket cashiers.

At the time of the first questionnaire, the workers subsequently lost to follow-up did not, with one exception, differ significantly from the rest of the target group for the frequency of upper-limb disorders, irrespective of the definition of a disorder (self-assessment of health or medical diagnosis). The exception was self-assessed shoulder pain, for which the frequency among those lost to follow-up (51%) was significantly higher than the frequency in the rest of the group (39%). The difference was mainly due to the subgroup of women less than 40 years of age, which included a large proportion of supermarket cashiers lost to follow-up.

For 47 of the 102 workers, some (minimal) information on their status at follow-up was available, either from the portion of the questionnaire they did complete or from the occupational health physician. Among this group, the most frequent reasons for the loss to follow-up were parental or maternity leave, resignation, and dismissal. Health reasons were reported less frequently.

The 598 workers with a complete questionnaire were also compared with those in the cross-sectional study who could not be included in the longitudinal analyses (because of the unavailability of the occupational health physician). The two groups differed. Those in the longitudinal study had a higher frequency of some disorders; for example, the prevalence of proved or suspected carpal tunnel syndrome was 21.9% in 1993–1994 among the 598 subjects in this study and 14.5% among those who could not be included in the longitudinal analyses. The corresponding figures for lateral epicondylitis were 12.2% and 11.2%.

Results

Prevalence at the beginning of the study and subsequent incidence of upper-limb disorders

The prevalence of proved or suspected carpal tunnel syndrome among the 598 subjects was 21.9% at the beginning of the study (table 2). The risk of the onset of the disorder during the 3-year interval was 12.2% (57

incident cases among the 467 without the syndrome) (table 2). Among the 57 cases, 20 were “proved in the medical examination”, 14 were “proved before the medical examination”, and 23 were “suspected” cases. For lateral epicondylitis the prevalence was 12.2% with an incidence of 12.2%. Among the 64 cases, 33 were “proved in the medical examination”, 16 were “proved before the medical examination”, and 15 were “suspected” cases. For wrist tendinitis the prevalence was 11.2% with an incidence of 5.7%. Fifteen of the 30 cases of hand or wrist extensor or flexor peritendinitis or tenosynovitis or De Quervain’s disease had at least one disorder proved in the examination. Seven cases of wrist tendinitis had only one (or several) suspected disorder(s).

Associations between incidence and risk factors at the beginning of the study

For each of the three disorders, the subjects with incident cases were compared with the subjects who remained unaffected by this specific disorder. The subjects affected by the disorder at the beginning of the study were excluded from the analysis.

Gender, age, activity sector, number of years on the job, smoking and the number of upper-limb disorders. Gender, number of years on the job, and smoking were not associated with the incidence of any type of disorder. Age, activity sector, and number of other upper-limb disorders were associated with the incidence of lateral epicondylitis, as table 3 shows. The comparison of these results with those for the prevalence at the beginning of the study (table 1) indicated similarities, but also discrepancies.

Gender was not associated with incidence, but it was associated with prevalence in that more women had carpal tunnel syndrome and more men had wrist tendinitis.

Working on an assembly line was a risk factor for both the prevalence and the incidence of lateral epicondylitis. Differences in the prevalence of carpal tunnel syndrome and wrist tendinitis across the activity sectors were either not found (carpal tunnel syndrome and packaging) or were attenuated (tendinitis and food industry) for incidence.

Both the prevalence and incidence of lateral epicondylitis increased with age.

Other personal and occupational risk factors. The associations significant at a P-level of ≥ 0.15 , which were taken into account in the logistic models, are presented in this section.

Somatic and depressive symptoms were not associated with carpal tunnel syndrome at the beginning of the study, but they were both significantly associated with lateral epicondylitis and wrist tendinitis.

A BMI increase of ≥ 2 kg/m² was associated with the incidence of wrist tendinitis and, for women only, with the incidence of carpal tunnel syndrome.

Among the 10 constraints included in the study, five were associated with the onset of one or several disorders. Having to drive screws repeatedly was a strong predictor of epicondylitis. On the other hand, those who said they had to drive screws were less at risk of wrist tendinitis. Tighten with force was a risk factor for both carpal tunnel syndrome and epicondylitis. Having to press with the hand was associated with carpal tunnel syndrome in an unexpected direction in that the risk increased for those who said they did not press with their hand. "Press with the elbow" was associated with the onset of both carpal tunnel syndrome and tendinitis. Hitting was associated with the incidence of tendinitis. Holding in position was a risk factor for carpal tunnel syndrome.

Two of the four job-related psychosocial factors in the analysis were associated with the subsequent incidence of at least one disorder. The incidence of wrist tendinitis was associated with social support at work. Job satisfaction at the beginning of the study was not significantly associated with the incidence of carpal tunnel syndrome for the overall sample, but an association was observed for the women.

Predictive factors for incidence

The logistic models initially included gender, age, and the risk factors associated with the incidence of the dis-

order. We chose not to include activity sector in the models in order to obtain a better understanding of the role of postural and biomechanical constraints, which differ according to sector. Tables 4 to 7 present the final models.

Carpal tunnel syndrome. Since the relations between carpal tunnel syndrome and the risk factors were different for the men and women, separate models are presented. The two models refer to different activity sectors. The men were predominantly employed in the food industry, packaging excluded; 17 of the 21 incident cases among the men came from this activity sector. Among the women, the predominant sector was work on an assembly line, 20 cases of carpal tunnel syndrome out of a total of 36 having occurred in this activity sector.

The models for the men and women used the same list of explanatory variables — all those associated with

Table 2. Three-year incidence of carpal tunnel syndrome, lateral epicondylitis, and wrist tendinitis.

	Carpal tunnel syndrome ^a		Lateral epicondylitis ^a		Wrist tendinitis ^a	
	N	% ^c	N	% ^c	N	% ^c
Prevalent cases at baseline	131	.	73	.	67	.
"Healthy" at baseline ^b	467	.	525	.	531	.
Incident cases	57	12.2%	64	12.2%	30	5.7%

^a Proved or suspected.

^b Without proved or suspected.

^c Incidence (risk in 3 years).

Table 3. Incidence of upper-limb disorders and age, sector, and number of upper-limb disorders at the beginning of the study. (NS = not significant)

	Carpal tunnel syndrome ^a (467 subjects; 57 incident cases)			Lateral epicondylitis ^a (525 subjects; 64 incident cases)			Wrist tendinitis ^a (531 subjects; 30 incident cases)		
	N ^b	Incidence ^c	P-value ^d	N ^b	Incidence ^c	P-value ^d	N ^b	Incidence ^c	P-value ^d
Sector									
Assembly	193	10.9	NS	197	17.3	0.04	226	3.5	NS
Clothing	46	17.4		60	8.3		61	6.6	
Food	124	15.3		133	11.3		113	8.0	
Packaging	71	8.4		95	9.5		92	7.6	
Cashiers	33	9.1		40	2.5		39	5.1	
Age									
≤29 years	101	11.9	NS	112	4.5	0.01	96	6.2	NS
30-39 years	173	15.6		206	11.2		200	7.5	
40-49 years	152	10.5		168	17.9		189	3.2	
≥50 years	41	4.9		39	15.4		46	6.5	
Number of other upper-limb disorders									
0	176	11.9	NS	176	7.9	0.01	176	5.7	NS
1	144	10.4		165	11.5		160	5.6	
2	85	12.9		111	12.6		113	2.6	
≥3	62	16.1		73	23.3		82	9.8	

^a Proved or suspected.

^b Number of subjects at the beginning of the study (free from the disorder).

^c Risk in a 3-year period (percentages).

^d Comparisons based on chi-square tests..

incidence for the men or the women, at a P-level of ≥ 0.15 , as well as age. The predictive factors in the final model differed for the men and women. For the men (table 4), the only determinants were three biomechanical constraints (tightening with force, holding in position, and not pressing with the hand). For the women (table 5), the variables associated with incidence were an increase in the BMI and a low level of job satisfaction.

Lateral epicondylitis. Of the nine potential determinants of lateral epicondylitis, two (age and "turn and screw") were associated with the incidence at a P-level of < 0.05 in the final model. Two other factors (number of other disorders

Table 4. Factors predicting the incidence of carpal tunnel syndrome for the men — results from the logistic model (not in the final model: increased body mass index, press with the elbow, job satisfaction). (OR = odds ratio, 95% CI = 95% confidence interval)

	Men ^a	
	OR	95% CI
Age		
≤29 years	1	.
30–39 years	1.05	0.34–3.25
≥40 years	0.46	0.10–2.04
Tighten with force		
No	1	.
Yes	4.09	1.43–11.7
Press with the hand		
No	1	.
Yes	0.28	0.09–0.82
Hold in position		
No	1	.
yes	3.59	1.06–12.1

^a 158 healthy at the beginning of the study; 21 incident cases.

Table 5. Factors predicting the incidence of carpal tunnel syndrome for the women — results from the logistic model (not in the final model: tighten with force, press with the hand, press with the elbow, hold in position). (OR = odds ratio, 95% CI = 95% confidence interval, BMI = body mass index)

	Women ^a	
	OR	95% CI
Age		
≤29 years	1	.
30–39 years	1.55	0.47–5.11
≥40 years	1.09	0.33–3.56
Increased BMI ≥ 2 kg/m ²		
No	1	.
Yes	2.38	1.04–5.47
Job satisfaction		
Medium or high level	1	.
Low level	1.79	0.84–3.84

^a 309 healthy at the beginning of the study; 36 incident cases.

at baseline and presence of depressive symptoms) remained in the final model ($P < 0.15$). Risk increased with age and the number of other disorders,

Table 6. Factors predicting the incidence of epicondylitis for the men and women — results from the logistic model (not included in the final model: somatic problems, tighten with force). (OR = odds ratio, 95% CI = 95% confidence interval)

	Epicondylitis ^a	
	OR	95% CI
Gender		
Male	1	.
Female	1.01	0.51–2.00
Age		
≤29 years	1	.
30–39 years	2.39	0.86–6.61
≥40 years	3.40	1.24–9.32
Number of upper limb diagnoses		
0	1	.
1	1.26	0.60–2.67
2	1.41	0.62–3.1
≥3	2.94	1.33–6.52
Depressive symptom(s)		
No	1	.
Yes	1.65	0.94–2.90
"Turn and screw"		
No	1	.
Yes	2.07	1.16–3.70

^a 525 healthy at the beginning of the study; 64 incident cases.

Table 7. Factors predicting the incidence of wrist tendinitis for the men and women — results from the logistic model (not in the final model: depressive symptoms, "turn and screw", press with the elbow). (OR = odds ratio, 95% CI = 95% confidence interval, BMI = body mass index)

	Wrist tendinitis ^a	
	OR	95% CI
Gender		
Male	1	.
Female	0.58	0.24–1.40
Age		
≤29 years	1	.
30–39 years	0.98	0.34–2.84
≥40 years	0.43	0.13–1.39
Increased BMI ≥ 2 (kg/m ²)		
No	1	.
Yes	2.2	0.92–5.26
Somatic problems		
No	1	.
Yes	3.78	1.63–8.75
Repetitive hitting		
No	1	.
Yes	2.16	0.84–5.56
Social support		
Yes	1	.
No	2.49	0.96–6.44

^a 531 healthy at the beginning of the study; 30 incident cases.

according to a clear gradient. Risk was higher for the subjects who declared they had to drive screws (OR 2.07, 95% CI 1.16—3.70) and those who had depressive symptoms at the beginning of the study.

The only psychosocial constraint initially included in the model (job control) did not remain in the final model.

Wrist tendinitis. The strongest predictor of the incidence of wrist tendinitis was the level of somatic problems at the beginning of the study (OR 3.78, 95% CI 1.63—8.75). The other risk factors associated with the incidence of this disorder were lack of social support, increased BMI, and having to “hit” repetitively. Age was also associated with the incidence. In contrast to the results for epicondylitis, the youngest workers were at increased risk. When an alternative score of somatic problems without “sleep disorders” was used, the results did not change, except that the odds ratio for somatic problems increased from 3.78 to 5.10 (95% CI 2.23—11.7).

Predictive factors for the incidence of proved diagnosis

When the final models presented in tables 4 to 7 were run with a stricter definition for incident cases (only proved diagnosis), no major changes in the magnitude of the odds ratios were observed. A part of the significant associations was no longer significant, possibly because of the smaller number of cases. However, among the women, the association between carpal tunnel syndrome and job satisfaction became significant, with an odds ratio of 2.87 (95% CI 1.13—7.29).

Discussion

The 598 workers in this longitudinal study were not selected according to health criteria, and the selection for health reasons between the first and second questionnaires was minimal. Some of the firms that participated in the cross-sectional part of the study were not included in the target group of the longitudinal study, for reasons related to the company or its occupational health physician. This step tended to exclude the less stable firms and those with a higher level of turnover. The occupational health physicians in the firms with a high level of upper-limb disorders volunteered more often for the longitudinal study. This characteristic of the study explains the high prevalence of carpal tunnel syndrome in the studied group at the beginning of the study.

The second stage of selection involved loss to follow-up. The 102 workers lost did not differ very much from the rest of the sample. Moreover, most of the work-

ers in the study, even those who suffered from upper-limb disorders in 1993—1994, were exposed to similar constraints at the beginning of the study and at the time of the follow-up.

The limited health selection of the study was probably due to workers who suffer from upper-limb disorders in repetitive work having no alternative to continuing to work in their jobs or in similar jobs. Financial considerations prevent them from stopping work, even if they have a disease for which they can receive compensation. It is difficult for them to find a job in another firm. A study of severe cases of lateral epicondylitis in France indicated that only 7% of the 105 previously active workers who suffered from epicondylitis had definitely stopped working for medical reasons (35). Over a 31-month period in a meat-processing factory in Finland, of 337 workers in strenuous manual jobs, only one stopped working because of an upper-limb illness, and job transfers were rare (27). In some contexts selection bias seems to be minimal (20, 23). Selection effects may be greater in the general population than in some prospective epidemiologic studies, since a prospective study is not feasible in a firm with a high level of turnover. A relatively high number of subjects indicated that their job or their workstation had changed in relation to health problems; therefore it seems that the firms in our study offered such possibilities. Selection effects may also differ according to the national or industrial rules for compensation and the possibilities for early retirement for health reasons (19).

We did, nonetheless, encounter difficulties related to health selection in interpreting our data. It is difficult to interpret results about the incidence of specific disorders in a group in which many workers are already affected at the beginning. The “healthy” workers at baseline represented a selected group, since they were unaffected despite a high level of occupational exposure. For example, more than 30% of the workers in packaging suffered from proved or suspected carpal tunnel syndrome in 1993—1994. The risk factors for subsequent carpal tunnel syndrome among those unaffected at that time may have been specific to those who withstood occupational constraints better than their colleagues through 1993—1994.

In our study the answers with respect to the pain and hand diagram from the self-administered questionnaires were omitted. However, the judgment of the occupational health physician was globally consistent with the responses to the self-administered questionnaire, even though the reference periods were not the same. For example, only 9 out of the 57 incident cases of carpal tunnel syndrome did not involve complaints of pain in the area supplied by the median nerve during the previous 6 months. One case, classified as a “proved diagnosis before the medical examination”, had had a successful carpal tunnel syndrome release 1 year before.

Another difficulty in our study was the participation of 18 different observers. Despite training for the physical examination at the beginning of the study, observer biases were observed, especially for shoulder disorders and, to a less extent, for lateral epicondylitis. For carpal tunnel syndrome the differences between the observers were minimal (29). However, they had no direct consequences in our study, since each worker was examined by the same occupational health physician in both examinations.

The figures for incidence are close in our study to the risk over this 3-year period. Hence they cannot be easily compared with figures from other prospective studies. For example, the 3-year risk for carpal tunnel syndrome was at least 12.2% for our population, since some of the cases that both began and ended in the 3-year period were not taken into account. This figure corresponds to an incidence rate of at least 4 per 100 person-years, which is about 4 times the incidence of probable or definite carpal tunnel syndrome for "handlers [and] laborers" in a prospective study of the general population (36). The incidence of strictly defined carpal tunnel syndrome was higher (11/100 person-years) in a meat-packing plant, whereas the prevalence rate of 21% was similar to that observed in our study (22).

A difficulty specific to longitudinal studies of upper-limb disorders is the paucity of knowledge on the temporal aspects of causality. It is generally assumed in epidemiology that a longitudinal design adequately answers questions about causality. This would be true in an experimental situation, and if we knew precisely the time lag between occupational exposure and the onset of the upper-limb disorder, but we did not. For example, a risk factor present at baseline is not necessarily a "new" risk factor. If it has strong short-term effects, the effect may have appeared before the beginning of the study, and no association with incidence would therefore be observed. This may have been the case for some of our risk factors, such as job demand.

The study design enabled us to include 18 different companies in various activity sectors. This was, on the whole, an advantage, but it did imply important limitations in the assessment of occupational exposure. The results relied on self-assessment of biomechanical constraints, which is not very precise (37).

Generally speaking, the biomechanical risk factors of our study can hardly be considered isolated risk indicators, since etiologically relevant exposures may be strongly correlated (28). The detailed results therefore cannot be easily extrapolated to other populations. In addition, the set of biomechanical constraints leading to a specific disorder depends on the principal potential constraints of the job. An example for this data set is the fact that the incident cases of carpal tunnel syndrome were not in the same activity sectors for the men and

women. Previous studies have also found that risk factors vary according to gender (22, 38).

This longitudinal study confirms the role of biomechanical hazards, which have so far been studied primarily in cross-sectional studies.

It also confirms that different disorders have different and specific biomechanical risk factors. Even with the imprecision of our diagnoses, and the fact that the three groups of incident cases are not mutually exclusive, the combination of risk factors differed for carpal tunnel syndrome, lateral epicondylitis, and wrist tendinitis. For epicondylitis, the results concerning the role of driving screws were expected. They were consistent both with the results of the cross-sectional study (29) and with results from the literature. Ritz (11), for example, found a positive dose-response relationship between epicondylitis and the duration of employment in jobs requiring forceful rotation in the elbow joint. For carpal tunnel syndrome, on the other hand, the relative discrepancies between the cross-sectional and longitudinal survey may be explained by the importance of risk factors experienced by women in high-risk sectors, especially packaging, in the cross-sectional study. The health selection effects discussed earlier may have played a different role for the men and women and for different activity sectors. Among the men, 11.2% were no longer at risk for carpal tunnel syndrome because they already had the disorder at the beginning of the study. The corresponding percentage for women was 26%. In packaging, which was a high-risk sector for prevalence, only five incident cases were observed among the women; this figure corresponds to a 3-year risk of 9.3.

The results concerning the incidence of carpal tunnel syndrome among the men highlight the importance of forceful movements (tighten with force, hold in position). Pressing with the hand appeared to be protective against the syndrome, whereas it had been, as expected, a risk factor for prevalence (29). Prolonged direct pressure on the palm has been found to be a risk factor for carpal tunnel syndrome (9). One explanation for the finding is that the results for the men described the risk factors in jobs such as meat-cutting in the food industry. This job exposes the workers to forceful movements, and the workers have to use a knife rather than their hands.

For wrist tendinitis, repetitive hitting was the only biomechanical factor in the final model. Other biomechanical factors may have short-term effects that would have been seen if the interval between the exposure and incidence had been shorter than 3 years.

The results from this longitudinal approach indicate that three sets of risk factors independently affect the incidence of upper-limb disorders. In addition to biomechanical constraints, psychosocial and personal factors play a role (39).

Prospective studies have shown associations between psychosocial factors at work and disorders of the neck, shoulder, and upper limbs (17). We observed that psychosocial factors affected the incidence of wrist tendinitis (social support) and carpal tunnel syndrome among women (job satisfaction), but not very strongly. It may be that psychosocial factors have relatively short-term effects which would be better seen with another study design, more precisely with a shorter interval between the exposure and the occurrence of the disorder.

The presence of depressive symptoms predicted the first occurrence of lateral epicondylitis, and the presence of somatic problems was a strong predictor of wrist tendinitis. This study confirms the predictive role of psychological problems for musculoskeletal disorders (40). It is not clear, however, whether these factors should be considered to be purely personal or, at least partly, to be responses to stressful work conditions other than the psychosocial work factors already taken into account in the model.

Smoking was not a risk factor in this study, although several prospective studies have observed an association with smoking (18). A BMI increase of ≥ 2 kg/m² was associated with the incidence of carpal tunnel syndrome among the women when we controlled for occupational exposures. This finding supports a causal link with weight and is consistent with results from cross-sectional studies (41) and one case-referent study (36). It was not predictive for the men however, but very few men had a BMI increase of ≥ 2 kg/m². The association between an increase in the BMI and wrist tendinitis was less expected.

The relations with age clearly differed from one disorder to another. The incidence of epicondylitis was significantly higher for older subjects, as its prevalence had been (29). On the other hand, workers aged 40 years or older were less likely to develop wrist tendinitis. The same contrast between epicondylitis and wrist tendinitis has been observed among a small group of workers by Roto & Kivi (32). The role of age in epicondylitis has also been stressed by other authors (11, 32).

Although lateral epicondylitis is also a kind of tendinitis, its strong and specific association with the number of other disorders suggests that overuse of the elbow, which is at the origin of epicondylitis, may be the consequence of other disorders, especially wrist disorders, that lead workers to modify motions they have previously used.

In conclusion, the results of this longitudinal study suggest that, in the future, more attention should be paid to cumulative health disorders among workers heavily exposed to biomechanical constraints in repetitive work. The subjects' history of disorders and of occupational exposure must both be taken into account. In addition, more attention should be paid to an assessment of the

psychosocial environment at work and to the relation of upper-limb disorders with psychological risk factors.

Acknowledgments

The study was conducted with financial support from INSERM. The study group on repetitive work consisted of JF Chastang, MF Landre, A Leclerc and I Niedhammer from INSERM U88; P Franchi and F Bourgeois from Agence Nationale pour l'Amélioration des Conditions de Travail (ANACT); P Mereau from Institut National de Recherche et de Sécurité (INRS); B Delemotte from Caisse Centrale de la Mutualité Sociale Agricole (CCMSA); M Gournay, MC Maillard, D Quinton, C Rondeau du Noyer, A Touranchet and C Vallayer from Inspection Médicale du travail; and the following 21 occupational health physicians: Drs Abele, Allard, Boutet, Camus, Charlanes, Dubosc, Gerbault, Kriegel, Lefevre, Lepri, Lisse, Lods, Malblanc, Mariel, Martin, Maugin, Prodhomme, Tobelem, Vaysse, Verhille, Weber. We thank V Bollongeat-Szeflel, M Chollet, S Desfontaines, I Le Pape, S Marie, C Martinet, F Papin, and A Zanea for their work at the regional level and N Kaniewski for the administration of the project.

References

1. Buckle P, Devereux J. Work-related neck and upper limb musculoskeletal disorders. Bilbao: European Agency for Safety and Health at work, 1999:114.
2. National Research Council. Work-related musculoskeletal disorders: a review of evidence. Washington (DC): National Academy Press, 1998:34.
3. Muggleton JM, Allen R, Chappell PH. Hand and arm injuries associated with repetitive manual work in industry: a review of disorders, risk factors and preventive measures. *Ergonomics* 1999;42(5):714—39.
4. Hales TR, Bernard BP. Epidemiology of work-related musculoskeletal disorders. *Orthop Clin North Am* 1996;27(4):679—709.
5. Hagberg M, Silverstein BA, Wells RV, Smith MJ, Hendrick HW, Carayon P, et al. Work related musculoskeletal disorders. Kuorinka I, Forcier L, editors. London: Taylor and Francis, 1995.
6. Riihimäki H. Back and limb disorders. In: Mc Donald JC, editor. *Epidemiology of work related diseases*. London: BMJ, 1995:207—38.
7. Scientific Committee for Musculoskeletal Disorders. Musculoskeletal disorders: work-related risk factors and prevention. *Int J Occup Environ Health* 1996;2:239—46.
8. Griffiths A, Buckle P, Cox T. Work-related upper limb disorders: a multidisciplinary approach. London: Taylor and Francis, 1998:192.
9. Viikari-Juntura E, Silverstein B. Role of physical load factors in carpal tunnel syndrome. *Scand J Work Environ Health* 1999;25(3):163—85.

10. Buckle PW. Work factors and upper limb disorders. *BMJ* 1997;315:1360—3.
11. Ritz BR. Humeral epicondylitis among gas- and waterworks employees. *Scand J Work Environ Health* 1995;21:478—86.
12. Moore JS. De Quervain's tenosynovitis: stenosing tenosynovitis of the first dorsal compartment. *J Occup Environ Med* 1997;39(10):990—1002.
13. Armstrong TJ, Buckle P, Fine LJ, Hagberg M, Jonsson B, Kilbom Å, et al. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. *Scand J Work Environ Health* 1993;19:73—84.
14. De Zwart BCH, Broersen JPJ, Frings-Dresen MHW, Vandijk FJH. Repeated survey on changes in musculoskeletal complaints relative to age and work demands. *Occup Environ Med* 1997;54:793—9.
15. Sedgwick AW, Davies MJ, Smith DS. Changes over 4 years in musculoskeletal impairment in men and women. *Med J Aust* 1994;161(8):482—6.
16. Nordstrom DL, De Stefano F, Vierkant RA, Layde PM. Incidence of diagnosed carpal tunnel syndrome in a general population. *Epidemiology* 1998;9(3):342—5.
17. Leino PI, Hänninen V. Psychosocial factors at work in relation to back and limb disorders. *Scand J Work Environ Health* 1995;21:134—42.
18. Leino-Arjas P. Smoking and musculoskeletal disorders in the metal industry: a prospective study. *Occup Environ Med* 1998; 55:828—33.
19. Cole DC, Hudak PL. Prognosis of nonspecific work-related musculoskeletal disorders of the neck and upper extremity. *Am J Ind Med* 1996;29:657—68.
20. Stål M, Moritz U, Johnsson B, Pinzke S. The natural course of musculoskeletal symptoms and clinical findings in upper extremities of female milkers. *Int J Occup Environ Health* 1997;3:190—7.
21. Gorsche R, Wiley JP, Renger R, Brant R, Gemer TY, Sasyniuk TM. Prevalence and incidence of stenosing flexor tenosynovitis (trigger finger) in a meat-packing plant. *J Occup Environ Med* 1998;40:556—60.
22. Gorsche R, Wiley JP, Renger RF, Brant RF, Gemer TY, Sasyniuk TM. Prevalence and incidence of carpal tunnel syndrome in a meat-packing plant. *Occup Environ Med* 1999; 56: 417—422.
23. Viikari-Juntura E, Kurppa K, Kuosma E, Huuskonen M, Kuorinka I, Ketola R, et al. Prevalence of epicondylitis and elbow pain in the meat-processing industry. *Scand J Work Environ Health* 1991;17:38—45.
24. Frost P, Andersen JH. Shoulder impingement syndrome in relation to shoulder intensive work. *Occup Environ Med* 1999;56:494—8.
25. Veiersted KB, Westgaard RH. Development of trapezius myalgia among female workers performing light manual work. *Scand J Work Environ Health* 1993;19(4):277—83.
26. Schibye B, Skov T, Ekner D, Christiansen JU, Sjøgaard G. Musculoskeletal symptoms among sewing machine operators. *Scand J Work Environ Health* 1995;21:427—34.
27. Kurppa K, Viikari-Juntura E, Kuosma E, Huuskonen M, Kivi P. Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. *Scand J Work Environ Health* 1991;17:32—7.
28. Punnett L. Ergonomic stressors and upper extremity disorders in vehicle manufacturing: cross-sectional exposure-response trends. *Occup Environ Med* 1998;55(6):414—20.
29. Leclerc A, Franchi P. Affections périarticulaires des membres supérieurs et organisation du travail: résultats de l'enquête épidémiologique nationale. Documents pour le Médecin du Travail, INRS 1996;65:13—31.
30. Leclerc A, Franchi P, Cristofari M-F, Delemotte B, Mereau P, Teyssier-Cotte C, et al. Carpal tunnel syndrome and work organisation in repetitive work: a cross sectional study in France. *Occup Environ Med* 1998;55:180—7.
31. Niedhammer I, Landre M-F, Leclerc A, et al. Shoulder disorders related to work organisation and other occupational factors among supermarket cashiers. *Int J Occup Environ Health* 1998;54:168—78.
32. Roto P, Kivi P. Prevalence of epicondylitis and tenosynovitis among meatcutters. *Scand J Work Environ Health* 1984; 10:203—5.
33. Viikari-Juntura E. Tenosynovitis, peritendinitis and the tennis elbow syndrome. *Scand J Work Environ Health* 1984; 10:443—9.
34. Dixon WJ, editor. BMDP statistical software. Berkeley (CA): University of California Press, 1983.
35. Guillaume S, Petry D, Chau N, Patris A, André JP, Merle M, et al. Impact socio-professionnel de l'épicondylalgie. *Arch Mal Prof* 1990;51(1)37—45.
36. Nordstrom DL, Vierkant RA, De Stefano F, Layde PM. Risk factors for carpal tunnel syndrome in a general population. *Occup Environ Med* 1997;54:734—40.
37. Wiktorin C, Karlqvist L, Winkel J, Stockholm MUSIC I Study Group. Validity of self-reported exposures to work postures and manual materials handling. *Scand J Work Environ Health* 1993;19:208—14.
38. Messing K, Tissot F, Saurel-Cubizolles M, Kaminski M, Bourguine M. Sex as a variable can be a surrogate for some working conditions. *J Occup Environ Med* 1998;40:250—60.
39. Buckle P. Upper limb disorders and work: the importance of physical and psychosocial factors. *J Psychosom Res* 1997; 43(1):17—25.
40. Leino P, Magni G. Depressive and distress symptoms as predictors of low back pain, neck-shoulder pain, and other musculoskeletal morbidity: a 10-year follow-up of metal industry employees. *Pain* 1993;53:89—94.
41. Nathan PA, Keniston RC. Carpal tunnel syndrome and its relation to general physical condition. *Hand Clin* 1993; 9(2):253—61.

Received for publication: 22 June 2000