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ORIGINAL ARTICLE

Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France (the Pays de la Loire study)

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Objective: To investigate the reasons for the excess risk of upper limb musculoskeletal disorders among manual workers compared with other workers in a random sample of 2656 French men and women (20–59 years old) participating in a study on the prevalence of work related upper limb disorders conducted by France's National Institute of Health Surveillance.

Methods: Prevalence ratios (PR) of physician-diagnosed musculoskeletal disorders of the shoulder, elbow, wrist, and hand (any of six leading disorders, rotator cuff syndrome, carpal tunnel syndrome) in manual versus non-manual workers were calculated using Cox regression models with a constant time of follow up and robust variance.

Results: 11.3% of men and 15.1% of women were diagnosed with an upper limb disorder. The risk was especially high in manual workers (PRs: 1.40 to 2.10). Physical work factors accounted for over 50% of occupational disparities overall, 62% (men) to 67% (women) for rotator cuff syndrome, and 96% (women) for carpal tunnel syndrome. The authors calculated that under lower levels of physical work exposures, up to 31% of cases among manual workers could have been prevented.

Conclusions: In working men and women, upper limb musculoskeletal disorders are frequent. Physical work exposures, such as repetitive and forceful movements, are an important source of risk and in particular account for a large proportion of excess morbidity among manual workers.

Work related musculoskeletal disorders of the upper limb are among the leading causes of morbidity and work disability in industrial countries. In the European Union, 17% to 30% of industry workers report musculoskeletal symptoms, and treatment and lost productivity cost billions of euros each year (0.5–2% of the Gross National Product).[1] In working populations, some of the key risk factors of upper limb disorders are work related physical exposures such as postural constraints or repetitive work gestures.[2]

Prevalence rates of musculoskeletal disorders and levels of exposure to physical work factors are especially high among manual workers (for example, painters, assemblers, mechanics, machine operators).[3] Yet the excess risk in manual compared to non-manual workers has rarely been studied. Our aims were to quantify (1) disparities in the risk of upper limb musculoskeletal disorders between manual and non-manual workers, and (2) the contribution of physical work exposures to these occupational disparities. We used data from the Pays de la Loire study, a cross sectional survey of 2685 randomly sampled French workers.

MATERIALS AND METHODS

Study population

The Pays de la Loire study was launched by France's National Institute for Health Surveillance to assess the prevalence of work related upper limb musculoskeletal disorders. It is set up in the Pays de la Loire region (Loire Valley district, West Central France, population 3 220 000) and data were collected with the concourse of a network of occupational physicians. In France, occupational medicine is a medical specialty and occupational physicians receive specialised four year training with a focus on occupational hygiene. Their tasks include monitoring work exposures and performing annual health examinations, which are mandatory for all workers. Each of the 7000 currently practicing occupational physicians simultaneously works across multiple companies and industries of the private sector, which employs about 70% of France's 25 million labour force (the self-employed, civil servants, and public sector employees benefit from particular occupational medicine arrangements).[4]

All 460 occupational physicians who practice in the Pays de la Loire region were solicited to participate in this study (each physician oversees the health of 1400–1700 to 2800–3200 workers, depending on whether he or she works part or full time). Eighty physicians agreed to participate and were trained by the investigators (YR assisted by a study coordinator) to perform a standardised physical examination, based on an international protocol for the evaluation of work related upper limb musculoskeletal disorders (SALTSA).[5]

Workers were included into the study from 1 January to 30 September 2002 and from 1 May to 30 October 2003. First, the investigators randomly selected 15 or 30 half days of consultation for each participating physician (depending on whether he/she worked part or full time). Next, each physician was asked to enroll every tenth worker undergoing a regularly scheduled annual health examination into the study. Thus, physicians followed a standardised random

Abbreviations: INSERM, Institut National de la Santé et de la Recherche Médicale; InVS, Institut National de Veille Sanitaire.

selection procedure, and were not able to choose study participants.

All participating workers (2685 men and women aged 20–59; on average: 20.7 participants per physician (SD 8.7)) were informed about the purpose of the study and gave informed consent to participate. This analysis was based on all participants with complete data: 1549 men and 1107 women. Participants were primarily employed in manufacturing (33%), trade (14%), and real estate (14%), followed by public administration (9%), health (7%), transport (6%), construction (6%), community services (3%), financial intermediation (3%), hotels and restaurants (2%), agriculture (2%), and education (1%).

Participating physicians were representative of the region's occupational physicians in terms of work time, geography, and economic sectors covered. Less than 10% of selected workers failed to participate (no shows, refusals) and workers' characteristics or the prevalence of upper limb disorders did not significantly vary by study year. Overall, in terms of age, occupational group and economic sector, the final sample was representative of the salaried workforce in the Pays de la Loire region and characteristic of France.[3]

Measures

Study procedures included a self-administered questionnaire followed by a medical examination. Participants reported their demographics (age: 18–29, 30–39, 40–49, 50–59; occupational grade: manager/member of an intellectual profession, professional/technician, clerk, manual worker—for example, painter, assembler, mechanic, machine operator,[6]) health characteristics (obesity, that is, <30 kg/m^2/$\geqslant 30$ kg/m^2; concurrent diabetes: no/yes; thyroid disease: no/yes; rheumatoid, other inflammatory or degenerative arthritis: no/yes; pregnancy: no/yes; a past history of upper limb disorders: no/yes), physical work exposures (based on the international SALTSA criteria document[5], see table 1) and musculoskeletal symptoms in the preceding 12 months (ascertained using the Nordic questionnaire[7]). Physicians checked study questionnaires for completeness.

Participants who reported symptoms of pain or parasthesia in the neck, shoulder/arm, elbow, hand/wrist, or fingers in the preceding 12 months underwent a localised physical examination. This examination was based on the international SALTSA criteria document,[5] and lead to the diagnosis of six principal upper limb disorders (rotator cuff syndrome-ICD10 M75.1, 75.2, epicondylitis-ICD10 M77.0, 77.1, cubital tunnel syndrome-ICD10-G56.2, extensor/flexor tendonitis/tenosynovitis ICD10-M70.0, 70.8, de Quervain's disease ICD10-G65.4, and carpal tunnel syndrome ICD10-G56.0).[8] For example, for rotator cuff syndrome, clinical tests included shoulder abduction, external and internal shoulder rotation, elbow flexion, active upper arm elevation (see Roquelaure *et al*[3] for a detailed description of the clinical examination).

Cases were defined as self-reported musculoskeletal symptoms at the time of the examination or during at least four days in the preceding week and physician observed physical abnormalities on the clinical examination. We used three study outcomes: any of the six principal upper limb disorders, and the two most frequent diagnoses: rotator cuff syndrome and carpal tunnel syndrome. Given our case definition, only symptomatic cases were considered. Participants who reported symptoms but did not fit the diagnostic criteria of a specific disorder were not considered as cases.

Statistical analysis

Our aim was to quantify the difference in the risk of upper limb disorders between manual versus non-manual workers, and to estimate the extent to which these occupational disparities are due to excessive physical work exposures. Prevalence ratios (PR) were calculated using Cox regression models with a constant time of follow up and robust variance.[9] We first estimated the prevalence ratio in manual workers compared with the non-manual, adjusting for age and individual risk factors of upper limb disorders (obesity, concurrent diabetes, thyroid disease, and arthritis) (Model 1). Next, we added repetitive movements at work (Model 2) and forceful movements (Model 3). Subsequent models estimated the contribution of physical work exposures associated with specific disorders. For rotator cuff syndrome: arms above shoulders, hands behind trunk, arms away from the body; for carpal tunnel syndrome: exposure to vibrations, wrist flexion. Finally, to estimate the overall contribution of physical work factors to manual workers' excess risk of upper limb disorders, we included all the above specified personal and physical work factors into a single statistical model. Physical work factors were moderately correlated (Pearson's correlation coefficients up to 0.37) and we found no significant interactions.

The contribution of each physical work exposure to manual workers' excess risk was calculated as follows: percent $= [(PR_{\text{adjusted for personal factors}} - PR_{\text{adjusted for personal factors+work exp}})/(PR_{\text{adjusted for personal factors}} - 1)]^*100$. Additionally, we estimated the number of cases that could have been prevented in manual workers under lower levels of exposure to physical work factors. This was achieved by applying the probability of disease observed in specific exposure groups in our study to all manual workers (for example, the probability among those exposed neither to repetitive nor forceful tasks was applied to all manual workers). There is no simple method to calculate confidence intervals for these estimates, hence they are not given.

Table 1 Description of physical work exposures (SALTSA protocol)

Occupational risk factors for multiple disorders of the shoulder, elbow, arm, wrist, hand	
Repetitive movements (same action >2 times per minute ⩾4 hours/day)	No (level 0) Yes, with an hourly 10 minute break (level 1) Yes, without an hourly 10 minute break (level 2)
Forceful movements (manipulating loads of >4 kg)	Never (level 0); <2 hours/day (level 1); ⩾2 hours/day (level 2)
Occupational risk factors for disorders of the shoulder	
Holding one or both arms above the shoulders	Never; <2 hours/day; ⩾2 hours/day
Reaching behind the trunk with one or both hands	Never; <2 hours/day; ⩾2 hours/day
Holding one or both arms away from the body	Never; <2 hours/day; ⩾2 hours/day
Occupational risk factors for disorders of the wrist or hand	
Exposure to vibrations	<2 hours/day; ⩾2 hours/day
Wrist flexion	<2 hours/day, ⩾2 hours/day

Table 2 Characteristics of the Pays de la Loire study population (%, p value comparing manual *v* non-manual workers)

	Men (n = 1549)			Women (n = 1107)		
	Non-manual occupation (n = 678)	Manual occupation (n = 871)	p Value	Non-manual occupation (n = 818)	Manual occupation (n = 289)	p Value
Age (years)						
18–29	18.6	28.4		24.2	22.8	
30–39	31.9	39.4	<0.0001	29.5	22.8	0.0826
40–49	31.7	25.1		30.4	37.0	
50–59	17.8	17.1		15.9	17.4	
Body mass index						
<30 kg/m^2	92.1	91.1	0.4965	94.5	85.1	<0.0001
⩾30 kg/m^2	7.9	8.9		5.5	14.9	
Diabetes						
No	98.1	98.2	0.9217	98.8	98.6	0.8386
Yes	1.9	1.8		1.2	1.4	
Thyroid disease						
No	97.2	99.0	0.0098	93.0	93.8	0.6602
Yes	2.8	1.0		7.0	6.2	
Arthritis						
No	97.8	98.5	0.2957	97.9	97.6	0.7405
Yes	2.2	1.5		2.1	2.4	
Employment sector						
Agriculture	2.2	4.2	<0.0001	1.0	7.5	<0.0001
Private (non-agricultural)	72.5	87.7		72.1	89.8	
Public	25.3	8.1		26.9	2.7	
Repetitive movements						
No	89.8	68.8	<0.0001	78.2	38.4	<0.0001
Yes, with breaks	8.3	25.2		18.3	37.4	
Yes, without breaks	1.9	6.0		3.5	24.2	
Forceful movements						
Never	76.3	4.1	<0.0001	82.8	61.3	<0.0001
<2 hours/day	16.4	29.0		12.1	20.4	
⩾2 hours/day	7.3	28.9		5.1	18.3	
Arm(s) above shoulder						
Never	78.0	41.5	<0.0001	69.9	57.8	<0.0001
<2 hours/day	16.4	37.4		20.3	22.5	
⩾2 hours/day	5.6	21.1		9.8	19.7	
Hand behind trunk posture						
Never	77.9	73.0	0.0380	78.2	84.1	0.0803
<2 hours/day	18.3	20.8		16.4	11.1	
⩾2 hours/day	3.8	6.2		5.4	4.8	
Arm(s) away from body						
Never	79.2	47.9	<0.0001	76.7	61.9	<0.0001
<2 hours/day	13.4	27.4		13.1	14.9	
⩾2 hours/day	7.4	24.7		10.2	23.2	
Exposure to vibrations						
<2 hours/day	84.5	49.5	<0.0001	95.5	81.6	<0.0001
⩾2 hours/day	15.5	50.5		4.5	18.4	
Wrist flexion						
<2 hours/day	67.8	24.5	<0.0001	61.0	24.9	<0.0001
⩾2 hours/day	32.2	75.4		39.0	75.1	
Musculoskeletal symptoms						
⩽12 months	47.2	56.4	0.0003	53.5	70.5	<0.0001
⩽7 days	24.0	29.4	0.0162	29.4	49.3	<0.0001
Any of 6 principal upper limb disorders*	8.5	13.4	0.0028	12.0	23.9	<0.0001
Rotator cuff syndrome (ICD10 M75.1)	4.6	8.5	0.0021	7.0	14.5	0.0001
Carpal tunnel syndrome (ICD10 G56.0)	1.9	2.5	0.4138	3.0	6.5	0.0089

*Includes rotator cuff syndrome, ICD10 M75.1; epicondylitis, ICD10 M77.1; cubital tunnel syndrome, ICD10 G56.2; extensor/flexor tendonitis/tenosynovitis, ICD10 G65.8; de Quervain's disease, ICD10 G65.4; carpal tunnel syndrome, ICD10 G56.0.

All analyses were conducted separately for men and women, using the SAS statistical package software[10] and Microsoft Excel.

The Pays de la Loire study received the approval of France's national committee for data protection (CNIL: Commission Nationale Informatique et Liberte).

RESULTS

We studied 1549 men and 1107 women with a mean age of 38 years (SD 10.3). 43.7% of men and 73.8% of women were employed in a manual occupation (for example, trade worker, plant and machine operator, or assembler). Male manual workers were somewhat younger than their non-manual counterparts (p<0.0001); to the contrary, female manual workers tended to be older than women employed in other occupational groups (p = 0.0826) and were also most likely to be obese (p<0.0001).

In our study population, 10.3% of men and 20.8% of women reported performing repetitive gestures at work; respectively 20.4% and 13.9% performed forceful movements, 20.6% and 18.0% worked with arms above their shoulders; 12.3% and 9.4% engaged in work tasks that required holding hands behind the trunk; 18.2% and 15.3% held their arms away from the body; 33.0% and 11.5% reported being exposed to vibrations; 53.8% and 57.1% performed work gestures that involved flexing the wrist. The frequency and intensity of physical work exposures were systematically highest among manual workers (p<0.0001 for all exposures, except holding hands behind the trunk, for which p = 0.0380 for men and p = 0.0803 for women). Repetitive movements

Table 3 Disparities in the risk of upper limb disorders between manual and non-manual workers in the Pays de la Loire study (age adjusted prevalence ratios (PR), 95% confidence intervals (95% CI))

		Any of six principal upper limb disorders*			
		Men (n = 1549; 175 cases)		Women (n = 1107; 167 cases)	
		PR (95% CI)	% Difference from Model 1	PR (95% CI)	% Difference from Model 1
Model 1†	Manual occupation	1.67 (1.24–2.24)	–	1.90 (1.44–2.51)	–
	BMI ⩾30 kg/m^2	1.56 (1.07–2.27)		0.90 (0.57–1.42)	
	Diabetes	1.32 (0.62–2.82)		2.72 (1.34–5.52)	
	Thyroid disease	0.46 (0.10–2.11)		1.00 (0.62–1.63)	
	Arthritis	0.95 (0.27–3.33)		1.09 (0.55–2.14)	
Model 2‡	Manual occupation	1.46 (1.08–1.97)	31	1.44 (1.07–1.94)	51
	Repetitive movements with breaks	1.72 (1.27–2.35)		1.76 (1.29–2.40)	
	Repetitive movements w/o breaks	1.98 (1.15–3.43)		2.25 (1.52–3.33)	
Model 3§	Manual occupation	1.48 (1.07–2.05)	28	1.83 (1.37–2.44)	8
	Force exertion: <2 hours/day	1.16 (0.79–1.68)		1.28 (0.89–1.82)	
	⩾2 hours/day	1.53 (1.07–2.16)		1.13 (0.69–1.85)	
Model 4§	Manual occupation	1.32 (0.95–1.84)	52	1.39 (1.02–1.89)	57
	Repetitive movements with breaks	1.68 (1.22–2.30)		1.75 (1.27–2.39)	
	Repetitive movements w/o breaks	1.95 (1.12–3.38)		2.30 (1.55–3.42)	
	Forceful movements: <2 hours/day	1.18 (0.82–1.70)		1.31 (0.91–1.87)	
	⩾2 hours/day	1.44 (1.00–2.06)		1.05 (0.65–1.71)	

*Includes rotator cuff syndrome, ICD10 M75.1; epicondylitis, ICD10 M77.1; cubital tunnel syndrome, ICD10 G56.2; extensor/flexor tendonitis/tenosynovitis, ICD10 G65.8; de Quervain's disease, ICD10 G65.4; and carpal tunnel syndrome, ICD10 G56.0.
†Adjusted for age.
‡Adjusted for age, obesity, diabetes, thyroid disease, arthritis.

were especially frequent among women, forceful movements among men.

In total, 52.4% of men (n = 814) and 57.9% of women (n = 642) reported upper limb musculoskeletal symptoms in the preceding year and underwent a physical examination (respectively 27.1% and 34.7% reported symptoms during the week preceding the interview). Physicians recorded a history of upper limb disorders in 19.4% of men and 26.5% of women, with 16.9% and 20.4% with past but not current disease. Female manual workers reported more past disease and musculoskeletal symptoms than their non-manual counterparts (32.5% compared with 19.9%, p ⩽ 0.0001). As shown in table 2, 175 men and 167 women were clinically diagnosed with an upper limb disorder (prevalence rates: 11.3% and 15.1%). Leading diagnoses were rotator cuff syndrome (men: n = 105, prevalence, 6.7%; women: n = 99, 8.9%) and carpal tunnel syndrome (men: n = 35, 2.2%; women: n = 44, 3.9%). As expected, physical work factors were associated with the risk of upper limb disorders (not shown).

Table 4 Disparities in the risk of rotator cuff syndrome (ICD10 M75.1) between manual and non-manual workers in the Pays de la Loire study (age adjusted prevalence ratios (PR), 95% confidence intervals (95% CI)

		Rotator cuff syndrome (ICD10 M75.1)			
		Men (n = 1549, 105 cases)		Women (n = 1107, 99 cases)	
		PR (95% CI)	% Difference from Model 1	PR (95% CI)	% Difference from Model 1
Model 1*	Manual occupation	2.07 (1.38–3.08)		1.90 (1.31–2.77)	
	BMI ⩾30 kg/m	1.42 (0.85–2.39)		1.01 (0.56–1.81)	
	Diabetes	1.42 (0.50–4.02)		1.77 (0.83–3.75)	
	Thyroid disease	0.80 (0.15–4.12)		0.82 (0.42–1.60)	
	Arthritis	0.91 (0.16–5.26)		2.35 (1.28–4.32)	
Model 2*	Manual occupation	1.72 (1.14–2.59)	33	1.40 (0.95–2.09)	56
	Repetitive movements with breaks	2.12 (1.43–3.15)		1.83 (1.21–2.74)	
	Repetitive movements w/o breaks	1.97 (0.93–4.17)		2.57 (1.50–4.41)	
Model 3‡	Manual occupation	1.81 (1.16–2.82)	24	1.88 (1.26–2.80)	2
	Forceful movements: <2 hours/day	1.09 (0.66–1.80)		1.11 (0.66–1.84)	
	⩾2 hours/day	1.65 (1.03–2.61)		1.03 (0.53–2.00)	
Model 4‡	Manual occupation	1.67 (1.11–2.52)	37	1.77 (1.20–2.60)	14
	Arm(s) above shoulder: <2 hours/day	1.06 (0.67–1.67)		1.21 (0.75–1.93)	
	⩾2 hours/day	2.57 (1.67–3.97)		1.75 (1.09–2.83)	
Model 5‡	Manual occupation	2.06 (1.37–3.09)	<1	1.96 (1.39–2.85)	+6
	Hand behind trunk posture: <2 hours/day	1.07 (0.68–1.68)		1.43 (0.88–2.32)	
	⩾2 hours/day	1.02 (0.44–2.36)		2.11 (1.13–3.93)	
Model 6‡	Manual occupation	1.84 (1.21–2.81)	21	1.63 (1.09–2.43)	30
	Arm(s) away from the body: <2 hours/day	1.49 (0.96–2.30)		1.23 (0.69–2.09)	
	⩾2 hours/day	1.42 (0.87–2.31)		2.13 (1.36–3.33)	
Model 7‡	Manual occupation	1.35 (0.86–2.12)	67	1.34 (0.88–2.03)	62

*Adjusted for age.
*Adjusted for age, obesity, diabetes, thyroid disease, arthritis.
‡Adjusted for age, obesity, diabetes, thyroid disease, arthritis, repetitive movements, force exertion, arm(s) above shoulder position, hand behind trunk posture, arm(s) away from body posture.

Table 5 Disparities in the risk of carpal tunnel syndrome (ICD10 G56.0) between manual and non-manual workers in the Pays de la Loire study (age adjusted prevalence ratios (PR), 95% confidence intervals (95% CI))

		Carpal tunnel syndrome (ICD10 G56.0)			
		Men (n = 1549, 35 cases)		Women (n = 1107, 44 cases)	
		PR (95% CI)	% Excess risk*	PR (95% CI)	% Excess risk
Model 1†	Manual occupation	1.40 (0.70–2.76)		2.10 (1.17–3.74)	–
	BMI ⩾30 kg/m	1.83 (0.68–4.88)		1.06 (0.40–2.73)	
	Diabetes	1.10 (0.13–8.85)		2.52 (0.28–22.43)	
	Thyroid disease	0 exposed cases		0.57 (0.14–2.30)	
	Arthritis	2.06 (0.29–14.36)		0 exposed cases	
Model 2‡	Manual occupation	1.34 (0.67–2.68)	15	1.33 (0.65–2.72)	70
	Repetitive movements with breaks	0.97 (0.39–2.44)		2.99 (1.45–6.18)	
	Repetitive movements w/o breaks	2.20 (0.64–7.60)		2.85 (1.08–7.52)	
Model 3‡	Manual occupation	1.41 (0.67–2.96)	–	1.81 (1.01–3.26)	23
	Vibrations: ⩾2 hours/day	0.97 (0.39–2.37)		3.29 (1.49–7.28)	
Model 4‡	Manual occupation	1.11 (0.49–2.54)	72	1.55 (0.84–2.87)	50
	Wrist flexion: ⩾2 hours/day	1.82 (0.83–3.98)		2.10 (1.11–3.97)	
Model 5§	Manual occupation	1.12 (0.49–2.56)	70	1.04 (0.51–2.11)	96

*% change from Model 1.
†Adjusted for age.
‡Adjusted for age, obesity, diabetes, thyroid disease, arthritis.
§Adjusted for age, obesity, diabetes, thyroid disease, arthritis, repetitive movements, force exertion, arm(s) above shoulder position, hand behind trunk posture, arm(s) away from body posture.

Findings for any of the six principal upper limb disorders

Adjusting for age, obesity, diabetes, thyroid disease and arthritis, manual workers were 1.67 (men) to 1.90 (women) times more likely than non-manual workers to be diagnosed with any of the six principal upper limb disorders (table 3, Model 1). Among men, 31% of this excess risk was related to repetitive movements at work (Model 2), 28% to forceful movements (Model 3). Among women, these work exposures explained 51% and 8% of manual workers' excess risk. Studied simultaneously, repetitive and forceful movements accounted for 52% of the excess risk among male manual workers and 57% among women (Model 4, PRs in manual workers: (men) 1.32, 95% CI 0.95 to 1.84; (women) 1.39, 95% CI 1.02 to 1.89).

Findings for rotator cuff syndrome

Compared to the non-manual, manual workers were at high risk of rotator cuff syndrome (PR adjusted for individual factors: 2.07 for men, 1.90 for women; table 4, Model 1). Repetitive movements (Model 2), forceful movements (men only, Model 3), and work postures that involve holding at least one arm above the shoulders or away from the body (women only, Model 4 and Model 6), explained 2–56% of this disparity in risk. Adjusting for all physical work exposures (Model 7), the manual/non-manual risk ratio decreased by 67% among men and 62% among women (fully adjusted PRs 1.35; 95% CI 0.86 to 2.12 and 1.34; 95% CI 0.88 to 2.03). Our results were robust when exposures with a small contribution to manual workers' risk (reaching behind the trunk in men and women and forceful movements in women) were excluded from the analysis (PRs in manual workers, respectively: 1.47; 95% CI 0.94 to 2.32 for men, and 1.29; 95% CI 0.85 to 1.93 for women).

Findings for carpal tunnel syndrome

For carpal tunnel syndrome, the manual/non-manual risk ratio adjusting for individual factors was 1.40 but not statistically significant in men, and 2.10 in women (table 5, Model 1). Among women, this disparity in risk between manual and non-manual workers was largely accounted for by physical work exposures (repetitive movements, Model 2: 70%, exposure to vibrations, Model 3: 23%, extreme wrist flexion, Model 4: 50%). Studied jointly (Model 5), physical work factors explained 96% of female manual workers' excess risk (after adjusting for all physical work factors, age, and health characteristics, the PR was reduced from 2.10 to 1.04 (95% CI 0.51 to 2.11).

Table 6 Predicted effect of a decrease in levels of physical work exposures* on the number of cases of upper limb disorders† among manual workers (871 men and 289 women)

	Men		Women	
	Cases (n)	Preventable (%)	Cases (n)	Preventable (%)
Expected in the study population	115.1	–	69.6	–
Decrease in exposure to repetitive movements (from level 2 to level 1)	114.6	<1	67.6	2.9
Decrease in exposure to forceful movements (from level 2 to level 1)	108.0	6.1	69.8	+ <1.0
Decrease in exposure to both repetitive and forceful movements (from level 2 to level 1)	108.22	6.0	69.9	+ <1.0
No forceful movements (level 0)	100.6	12.6	71.6	+2.8
Decrease in exposure to repetitive movements (from level 2 to level 1) + no forceful movements (level 0)	100.5	12.7	70.0	+ <1.0
No repetitive movements (level 0)	97.7	15.0	46.7	32.8
No repetitive movements (level 0) + decrease in exposure to forceful movements (from level 2 to level 1)	90.8	21.0	48.5	30.3
No repetitive or forceful movements (level 0)	87.6	23.8	47.7	31.4

*Repetitive movements: level 0, no exposure; level 1, exposure, with an hourly 10 minute break; level 2, exposure, without an hourly 10 minute break. Forceful movements: level 0, no exposure; level 1, <2 hours/day; level 2, ⩾2 hours/day
†Includes rotator cuff syndrome, ICD10 M75.1; epicondylitis, ICD10 M77.1; cubital tunnel syndrome, ICD10 G56.2; extensor/flexor tendonitis/tenosynovitis, ICD10 G65.8; de Quervain's disease, ICD10 G65.4; carpal tunnel syndrome, ICD10 G56.0.

Preventable cases of upper limb disorders

Among manual workers, up to 23.8% of cases observed in men and up to 31.4% in women would not have occurred under lower levels of exposure to physical work factors (table 6). The largest reductions in risk would have been achieved if none of the workers were exposed to repetitive movements (defined as performing the same action more than two times per minute for four or more hours per day) or forceful movements (defined as manipulating loads of more than 4 kg).

In 2004, 6 127 000 French men and women were employed in a manual occupation;[6] assuming prevalence rates of 11.3% in men and 15.1% in women, about 720 000 probably suffered from upper limb disorders. Based on our estimates, up to 197 000 cases could have been prevented had levels of physical work exposures been lower.

DISCUSSION

Main findings

In our study, 11.3% of men and 15.1% of women suffered from a clinically significant upper limb musculoskeletal disorder. Prevalence rates were systematically higher among participants working in manual than in non-manual occupations. In men, this disparity between manual and non-manual workers was highest for rotator cuff syndrome, in women for carpal tunnel syndrome. Over 50% of the excess risk in manual workers was explained by physical work exposures, particularly repetitive movements at work. Forceful movements played a key role among men. Upper limb musculoskeletal disorders are an important public health problem, and physical work factors appear as a key source of risk and disparities between occupational groups.

Study limitations

Our study was cross sectional and, in principle, the associations observed may be spurious.[11] Reassuringly, the relation between biomechanical work exposures and upper limb disorders is biologically plausible and has been shown in prospective studies.[12–16] Additionally, under exposure to physical work factors, latency periods for upper limb musculoskeletal disorders of the type we studied can be as short as several weeks.[17 18] In our study population, 87% of men and women worked in the same job for over a year; thus, we believe that prevalent disorders were associated with occupational exposures on the most recent job. Advantages of a cross sectional design are that we were able to collect detailed exposure and outcome data in a large sample of the working population.

A potential source of bias is occupational physicians' low participation rate (17%). However, French occupational physicians work across multiple companies and work sectors,[4] and those who participated in the Pays de la Loire study were representative of the region's physicians in terms of work time, geography, and economic sectors covered. Nonetheless, we acknowledge that physicians who took part in the study may have been particularly concerned by workers' musculoskeletal health. Additionally, physicians had access to participants' data before the clinical examination, which may have lead to information bias.

Bias in the selection of participating workers is unlikely, because in France annual occupational health visits are mandatory and physicians were not able to select study participants. Across our study's two waves of data collection (2002 and 2003), participants' characteristics were comparable and representative of the region's workforce in terms of geography, economic sector, and occupational group. The prevalence of biomechanical exposures corresponds to what could be expected, except for a high level of exposure to vibrations (over 50% of male manual workers, compared to about 30% in other studies).[19] This is probably due to our broad exposure definition, which covered vibrating handheld tools as well as machines such as a conveyor belt. Overall, the prevalence of upper limb disorders in the Pays de la Loire study is comparable to previous general population studies[20] and with the large number of participating physicians and workers, we believe that our study did not suffer from systematic bias.

Workers who experience pain may overrate their physical work exposures, and to limit potential bias, we used standardised measures of physical work exposures and disease status.[5] Exposure misclassification, if it did occur, could lead to erroneous estimations of the effects of work factors, and it is reassuring that the relative risks we report (approximately 2.0 for repetitive movements for men and women and 1.5 for forceful movements for men) are consistent with previously published international estimates (2.3–8.8 for repetitive movements, 1.8–9.0 for forceful movements).[2] More broadly, workers' evaluations of physical exposures are probably accurate.[2 16]

Finally, as other investigations conducted in occupational settings, our study was subject to the healthy worker effect, whereby individuals who were not in the labour force due to musculoskeletal disease could not be included. However, the prevalence of upper limb disorders is generally higher among employed men and women than in the general population (for example, 4.5 and 6.1% for physician diagnosed shoulder tendonitis and 4.7 and 7.9% for discrete hand and wrist disorders in a British study,[20 21] 2.8 and 4.6% for clinically certain carpal tunnel syndrome in Sweden[22]), highlighting the critical role of work as a source of risk.

Physical work exposures and occupational disparities in the risk of upper limb disorders

In our study, upper limb disorders were 1.40 to 2.10 times more frequent among men and women working in manual jobs than among workers in non-manual occupations. Our aim was to estimate the extent to which this disparity in risk was the result of biomechanical work exposures.[23 24] Therefore, our statistical models simultaneously included manual work status and biomechanical work exposures. This may appear unusual, especially as biomechanical work exposures can partly be considered as intermediate variables in the relation between manual work status and upper limb disorders: in an aetiological study examining the risk associated with physical work factors one would not simultaneously include manual work status and physical work exposures. However, our hypothesis was that not all manual workers are exposed to similarly high levels of physical work demands and that we could therefore estimate the share of manual/non-manual risk differences due to biomechanical work exposures.

In the Pays de la Loire study, over 50% of manual workers' excess risk of upper limb disorders is related to work gestures that are repetitive, forceful, or constraining, and which constitute known risk factors of shoulder, elbow, wrist, or hand disorders.[12–15 25] In women, physical work exposures explain 96% of the manual/non-manual difference in the risk of carpal tunnel syndrome, which is high and will need to be confirmed in other populations. While the biophysiological mechanisms involved have not been fully elucidated, physical exposures that exceed the internal tolerance of soft tissues can lead to muscle/tendon injury, which becomes manifest as inflammation (for example, tendonitis) and favours nerve damage or entrapment (for example, carpal tunnel syndrome). These in turn result in pain, neurological symptoms, and functional impairment.[2 26] It is important to note that since the mechanisms of musculoskeletal upper limb disorders are not well understood, we can only speculate

that the contribution of physical work factors observed in our study reflects true causal associations.

Other important risk factors of upper limb disorders besides work factors include age, obesity, diabetes, thyroid disease, and arthritis, which we systematically controlled for in our analyses.[27] Three participants were pregnant at the time of the study, and excluding them would not have modified our findings. We had no information on recreational activities (for example, sports) or women's hormonal treatment and menopause status,[2 28] but there is no indication that these potential risk factors are more frequent among manual workers and contribute to occupational disparities in upper limb disorders. Psychosocial factors, both work related (for example, job stress, job satisfaction, social support from coworkers) and personal (for example, symptoms of depression) have also been associated with upper limb disorders.[29] Yet, with the exception of neck problems, which we did not study, their effects are thought to be predominantly mediated by physical exposures.[29 30] Still, personal and organisational factors probably influence the frequency and intensity of biomechanical exposures, indirectly shaping the risk of musculoskeletal disorders at the individual and population levels.

Working in a manual occupation implies exposure to physical work demands, yet among manual workers the levels and types of physical exposures vary. The aim of our study was to show that changes in levels of biomechanical exposures could lead to decreases in the risk of upper limb disorders. Our findings suggest that, after adjustment for individual risk factors, decreases in forceful and repetitive movements could lead to the prevention of up to a third of cases occurring in manual workers.

Conclusion

Manual workers are at high risk of upper limb disorders, which are a leading cause of morbidity and disability. The specific contribution of physical work factors to manual workers' excess morbidity varies depending on the prevalence of exposure in the population, yet overall, lowering requirements for forceful and repetitive work gestures could reduce the prevalence of upper limb disorders as well as decrease occupational disparities in this area.

Main messages

- Musculoskeletal disorders of the hand, wrist, elbow, arm, and shoulder are frequent in the working population (prevalence rates of 11.3% in men, 15.1% in women).
- The risk of upper limb disorders is systematically higher in manual than in non-manual workers (prevalence ratios ranging from 1.44 to 2.10).
- Physical work exposures, and particularly repetitive and forceful gestures, account for over 50% of manual workers' excess risk of upper limb disorders.

Policy implications

- Reducing physical exposures at work could decrease the number of cases of upper limb disorders in the working population, particularly among manual workers (decrease of up to 23–31% in men and in women).

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(1) b; (2) e; (3) c; (4) a; 5 (d)