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**Key terms:** [biomechanical exposure](#); [biomechanics](#); [cohort study](#); [France](#); [Gazel cohort](#); [long-term effect](#); [occupational disease](#); [occupational exposure](#); [occupational exposure](#); [shoulder pain](#)

## Long-term effects of biomechanical exposure on severe shoulder pain in the Gazel cohort

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**Objective** We aimed to assess whether the risk factors for severe shoulder pain, especially exposure to arm elevation, were still relevant after a 12-year follow-up, even following retirement.

**Methods** All men participating in the ARPEGE ancillary study of the GAZEL cohort (followed-up since 1989) and who answered the 1994 or 1995 general GAZEL self-administered questionnaire were included. Weight and self-reported exposure (arm elevation >90° with and without carrying loads) over the entire working life were collected at baseline (1994–1995). Shoulder pain and its intensity were recorded in 1994–1995 and again in 2006. Shoulder pain was measured on an intensity or discomfort 6-point scale in 1994–1995 and on an 8-point scale in 2006. Severe shoulder pain was defined as point-rated higher than the mid-points (>3/6 in 1994–1995 and >4/8 in 2006) while moderate pain was lower or equal to these thresholds.

**Results** At baseline, 1786 47–51-year-old men were included. In 1994–1995, moderate pain was observed among 8.5% (N=151) of men and severe shoulder pain among 14.6% (N=261). Exposure to arm elevation >90° while carrying loads was significantly associated with severe shoulder pain with >25 years of exposure [adjusted odds ratio (OR<sub>adj</sub>) 4.2, 95% confidence interval (95% CI) 1.7–10.5], taking into account age, sports, smoking habits, history of shoulder trauma, and body mass index. In 2006, when most of the subjects had retired, 1482 men (83.0%) answered the questionnaire, 17.3% of them with severe shoulder pain; the association between exposure to arm elevation >90° while carrying loads and severe shoulder pain was still significant (OR<sub>adj</sub> 3.3, 95% CI 1.3–8.0), and remained so when subjects with shoulder pain at baseline were excluded.

**Conclusions** Among men, the effect of high shoulder exposure (arm elevation >90° while carrying loads) during working life on severe shoulder pain remains even after retirement. Extended surveillance and prevention should be offered to these workers.

**Key terms** biomechanics; cohort study; France; occupational disease; occupational exposure.

Shoulder pain is a relatively common condition and a cause of disability in the general population. The 12-month prevalence of shoulder pain in the general population ranges between 7–47% depending on the population studied and the definition used (1, 2). Silverstein et al (3) reported a claim incidence rate for shoulder disorders of 54.0 per 10 000 workers per year in the US. In France, neck and shoulder disorders incidence

was 7.3% and 12.5% among men and women, respectively, between 1990–1995 (4), and the 3-year incidence in a high repetitive work population setting was 29% among men and 21% among women (5). In the Cosali survey, the prevalence of the syndrome of the rotator cuff was 7% in 2002–2004, with 65% of persistence of shoulder symptoms three years later (6, 7).

Some reviews have summarized the known occupa-

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tional risk factors of shoulder pain and disorders (8–10): the biomechanical factors associated with shoulder pain and rotator cuff syndrome are shoulder abduction and flexion, heavy lifting, forceful manual exertion, repetitive movements, use of vibrating hand tools and cumulative exposure to these factors. Although true inflammatory tendinopathies exist, most workers have prolonged shoulder symptoms that correspond histologically to the degeneration of the normally highly arranged collagen fiber structure (11). Considering these elements, it could be hypothesized that occupational determinants of shoulder disorders are involved not only when they are present, but also long afterwards. A prospective study in a general population found that physical workload increases the risk of subsequent clinical shoulder disorders and that the effects seem to be long-term (12), but the effect of retirement (ie, cessation of exposure) was not examined.

We studied a sub sample of men from the GAZEL cohort (the ARPEGE study) to investigate whether known occupational factors associated with severe shoulder pain at baseline were still relevant 12 years later, even after retirement.

## Methods

### Cohort

The GAZEL cohort was established in 1989. Its members are volunteers recruited among the employees of Electricité de France and Gaz de France (EDF-GDF), the French national utility for energy production and distribution. EDF-GDF employed approximately 150 000 workers of diversified trades and socioeconomic status throughout France. At baseline in 1989, the cohort included 20 625 volunteers, men aged 40–50 and women 35–50 years. In January of each year (including 1994, 1995, and 2006), participants receive a general questionnaire about their lifestyle, health and occupational situation. In addition, more than 40 ancillary research projects explore specific themes, some using additional specific questionnaires (13).

### Sample

The ARPEGE ancillary study was designed to analyze musculoskeletal disorders of the upper and lower limbs (14). In 1994–1995, a sample was selected among GAZEL participants, including all blue-collar and clerical workers, half of the managers, and one quarter of the supervisors. In the present study, we included only the ARPEGE study men who answered the 1994 or the 1995 general GAZEL self-administered questionnaire

(see figure 1). Women were not included in these analyses because of the low prevalence of their exposure to biomechanical factors.

### Exposure and covariates

In 1994–1995 (baseline), all included subjects filled out both the annual GAZEL and the specific ARPEGE self-administered questionnaires. Therein were recorded: age, body mass index (BMI) [continuous variable divided into four categories:  $\geq 18.5$ – $< 25$  kg/m<sup>2</sup> (normal),  $< 18.5$  kg/m<sup>2</sup> (underweight),  $\geq 25$ – $< 30$  kg/m<sup>2</sup> (overweight),  $\geq 30$  kg/m<sup>2</sup> (obese)], regular sports activity (yes/no), current smoker (yes/no), and previous major shoulder trauma (fracture, luxation: yes/no). Self-assessed lifetime occupational exposures for shoulders were also recorded. Based on preliminary analyses (15), the most relevant exposures were “arm elevation  $> 90^\circ$  while carrying loads” and “arm elevation  $> 90^\circ$  without carrying loads”. Three categories were considered based on duration of exposure assessed at baseline: never exposed or exposed for  $< 1$  year, 1–25 years, and  $\geq 25$  years of exposure.

Information about socioprofessional group was recorded in 1989, and coded into 11 categories, such as blue-collar workers, technical supervisors, managers etc. Since age at retirement is rather early in France, especially at EDF-GDF, almost all subjects had retired by 2006.

### Outcome variables

The main outcome variable considered in this study was severe shoulder pain in the previous year. At baseline, it was defined in the ARPEGE self-administered questionnaire as pain or discomfort of  $> 3$  on a 6-point scale (one question). In the longitudinal analysis, severe shoulder pain was defined as pain or discomfort of  $> 4$  on an 8 point-scale in the 2006 GAZEL self-administered questionnaire. Moderate pain was defined as pain rating lower than these thresholds.

### Analysis

Associations between occupational and personal factors, and moderate or severe shoulder pain at baseline (cross-sectional analyses) were described using bivariate analyses (Chi square test). Multivariate analyses were performed using logistic regression: simple models were based on severe shoulder pain versus moderate and no pain grouped together, and a multinomial model was based on moderate versus no pain and severe versus no pain.

The association between factors present at baseline in 1994–1995 and moderate or severe shoulder pain 12 years later in 2006 (longitudinal analyses) was assessed using similar models, with two separate models: one

among men without any shoulder pain at baseline (multinomial logistic model) and one among those who reported shoulder pain at baseline (either moderate and severe, simple logistic model. Another variable (“having retired before January 1<sup>st</sup>, 2001”) was added to take into account early retirement. In the analysis among men with pain, severe intensity at baseline was also.

SAS, version 9.1, was used for all statistical analyses (SAS Institute Inc, Cary, NC, USA). Associations were considered statistically significant if the P-value was <0.05.

## Results

### Cross-sectional analysis

In 1994–1995, 1786 men answered the GAZEL and ARPEGE questionnaires (figure 1) and constituted the baseline sample. They were aged 47–51 years; 8.5% had moderate shoulder pain (N=151) and 14.6% (N=261) had severe shoulder pain; 54.7% (N=976) of subjects had a BMI  $\geq 25$  kg/m<sup>2</sup> [including 9.1% (N=163) with a BMI  $\geq 30$  kg/m<sup>2</sup>, table 1]. Arm elevation >90° while carrying

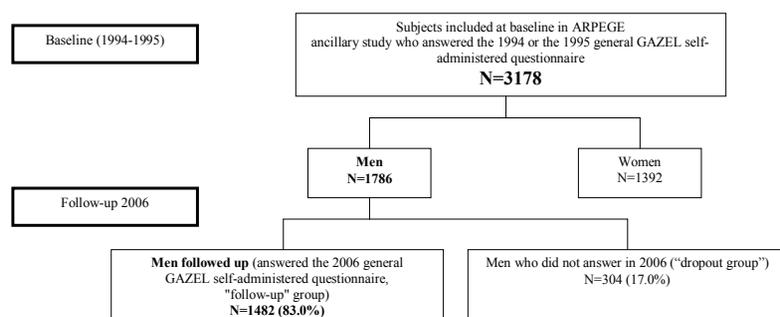


Figure 1. Flow diagram.

**Table 1.** Association between shoulder pain in 1994–1995 and personal and occupational factors assessed in 1994–1995 (bivariate analyses). [OR=odds ratio; 95% CI=95% confidence interval; BMI=body mass index]

	Total		Moderate shoulder pain				Severe shoulder pain						
	N	Mean	SD	Cases (N)	%	OR (crude)	95% CI	Mean	SD	Cases (N)	%	OR (crude)	95% CI
Age (years)	48.8 <sup>a</sup>	48.8	1.33			0.99	0.88–1.12	48.9	1.36			1.03	0.94–1.31
BMI (kg/m <sup>2</sup> )	26.1 <sup>b</sup>	26.8	3.20			1.07 <sup>c</sup>	1.02–1.13	26.3	3.20			1.02	0.98–1.08
BMI (class, kg/m <sup>2</sup> )													
<18.5	198			40	8.08	1.24	0.67–2.27			26	13.13	0.90	0.56–1.45
18.5–25	612			16	6.54	1.00				89	14.54	1.00	
25–30	813			77	9.47	1.51 <sup>c</sup>	1.01–2.25			120	14.76	1.06	0.78–1.43
$\geq 30$	163			20	12.27	2.06 <sup>c</sup>	1.16–3.66			26	15.95	1.21	0.75–1.95
Current smoker													
No	1386			131	9.45	1.00				203	14.65	1.00	
Yes	400			22	5.50	0.55 <sup>c</sup>	0.35–0.88			58	14.50	0.94	0.60–1.29
History of shoulder trauma													
No	1575			118	7.49	1.00				211	13.40	1.00	
Yes	211			35	16.59	2.93 <sup>c</sup>	1.93–4.46			50	23.70	2.34 <sup>c</sup>	1.64–3.35
Regular sports													
No	1301			118	9.07	1.00				194	14.91	1.00	
Yes	485			35	7.22	0.77	0.52–1.14			67	13.81	0.89	0.66–1.21
Exposed to arm elevation >90° while carrying loads (years)													
<1	1396			117	8.38	1.00				172	12.32	1.00	
1–25	301			25	8.31	1.13	0.72–1.79			67	22.26	2.06 <sup>c</sup>	1.50–2.84
$\geq 25$	89			11	12.36	1.86	0.95–3.65			22	24.72	2.53 <sup>c</sup>	1.51–4.25
Exposed to arm elevation >90° without carrying loads (years)													
<1	1252			102	8.15	1.00				157	12.54	1.00	
1–25	395			35	8.86	1.22	0.81–1.83			80	20.25	1.81 <sup>c</sup>	1.34–2.44
$\geq 25$	139			16	11.51	1.57	0.89–2.77			24	17.27	1.53	0.95–2.47
Total	1786				153					261			

<sup>a</sup> SD=1.38.

<sup>b</sup> SD=3.10.

<sup>c</sup> P<0.05.

loads was found mostly among blue-collar workers and technical supervisors [N=285/871 (32.7%) versus 98/880 (11.1%) for the other categories, P<0.0001].

Regular practice of a sport or being a current smoker, were not statistically associated with shoulder pain in 1994–1995 (table 1). BMI was associated with moderate shoulder pain but not with severe shoulder pain. The same association was found for history of previous shoulder trauma. Arm elevation >90° while carrying loads (in working life) was significantly associated with shoulder pain, especially severe shoulder pain. After adjusting for age, BMI, regular sports, and history of shoulder trauma, exposure to arm elevation >90° while carrying loads remained significantly associated with severe shoulder pain at baseline (simple logistic model, table 2). A dose–response relationship was found between severe shoulder pain and duration of exposure in both the simple logistic and the multinomial models (table 2). Arm elevation >90° without carrying loads was not significantly associated with shoulder pain in any of the models.

**Follow-up**

Among respondents in 1994–1995, 304 men (17.0%) did not answer the 2006 questionnaire (drop-out group). The other men were followed until 2006 (follow-up group). In 1994–1995, more subjects in the follow-up group declared having been exposed to arm elevation >90° without carrying loads in their working life than in the

drop-out group. The proportion of subjects exposed to arm elevation >90° without carrying loads was 31.1% (N=461) in the follow-up group, versus 24.0% (N=73) in the drop-out group (P<0.05). Being overweight (BMI ≥25 kg/m<sup>2</sup>, obesity included) was also more frequent in the follow-up group (58.4%, N=865 versus 36.5% N=111 respectively, P<0.0001). However, the prevalence of severe shoulder pain at baseline was not significantly different between the two groups (13.2%, N=196 in the follow up group versus 10.5%, N=32 in the drop-out group, P>0.05). Mean age was not statistically different between the two groups [48.8 years, standard deviation (SD) 1.3 in both groups, P>0.05]. The proportion of subjects exposed to arm elevation >90° while carrying loads was 22.7% (N=336) in the follow-up group, versus 17.8% (N=54) in the drop-out group (P=0.06).

**Evolution between 1994–1995 and 2006**

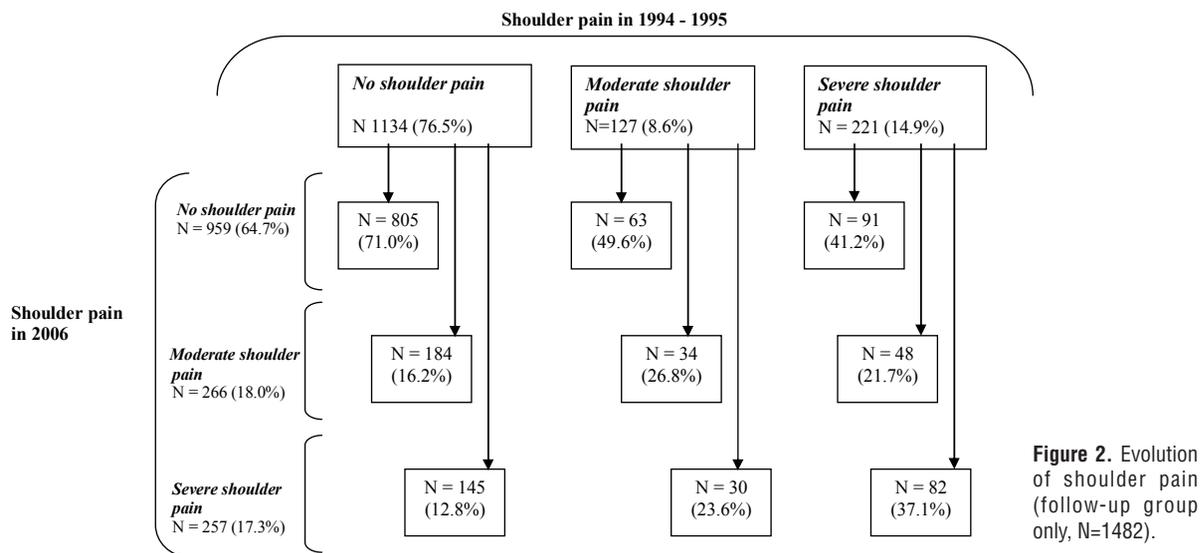
Among the 1482 men in the follow-up group, the prevalence of severe shoulder pain in 2006 was higher than at baseline (17.3%, N=257 versus 14.9%, N=221, figure 2); the mean age was 60.8 (range 59–63) years old, and 98% had retired (55.7% of men retired before 1 January 2001, N=826). The prevalence of shoulder pain (severe and moderate) was also higher in 2006 than at baseline (35.3%, N=523 versus 23.5%, N=348).

Among the 231 men in the follow-up group who had severe shoulder pain in 1994–1995, 82 (37.1%) also had severe shoulder pain in 2006, whereas among the 1134

**Table 2.** Association between moderate and severe shoulder pain in 1994–1995 and personal and occupational factors assessed in 1994–1995 (multivariate analyses). [OR<sub>adj</sub>=adjusted odds ratio; 95% CI=95% confidence interval; BMI=body mass index]

	Simple logistic model		Multinomial logistic model			
	Severe shoulder pain versus no or moderate shoulder pain		Moderate shoulder pain versus no shoulder pain		Severe shoulder pain versus no shoulder pain	
	OR <sub>adj</sub>	95% CI	OR <sub>adj</sub>	95% CI	OR <sub>adj</sub>	95% CI
Age (years)	1.04	0.94–1.15	1.00	0.88–1.14	1.04	0.94–1.16
BMI (kg/m <sup>2</sup> )	1.00	0.96–1.05	1.06 <sup>a</sup>	1.01–1.12	1.01	0.96–1.06
Current smoker						
No	1.00		1.00		1.00	
Yes	0.94	0.67–1.33	0.55 <sup>a</sup>	0.33–0.90	0.89	0.62–1.26
History of shoulder trauma						
No	1.00		1.00		1.00	
Yes	1.92 <sup>a</sup>	1.31–2.81	3.09 <sup>a</sup>	1.96–4.88	2.27 <sup>a</sup>	1.53–3.36
Regular sports						
No	1.00		1.00		1.00	
Yes	0.87	0.63–1.21	0.62	0.40–0.96	0.83	0.60–1.15
Exposed to arm elevation >90° while carrying loads						
<1 year	1.00		1.00		1.00	
1–25	1.57 <sup>a</sup>	1.03–2.39	0.95	0.53–1.71	1.56 <sup>a</sup>	1.02–2.39
≥25	3.21 <sup>a</sup>	1.46–7.07	1.52	0.56–4.12	3.38 <sup>a</sup>	1.51–7.55
Exposed to arm elevation >90° without carrying loads						
<1 year	1.00		1.00		1.00	
1–25	1.42	0.96–2.10	1.27	0.75–2.13	1.45	0.98–2.17
≥25	0.73	0.35–1.52	1.27	0.55–2.93	0.75	0.36–1.58

<sup>a</sup> P<0.05.



who did not report pain at baseline, 12.8% (N=145) had severe shoulder pain in 2006 (figure 2).

The difference in prevalence of severe shoulder pain between men who retired before 1 January 2001 and those who retired later was not statistically significant (18.6% versus 16.9%,  $P>0.05$ ).

#### Association between the baseline variables and severe shoulder pain in 2006

Exposure to arm elevation  $>90^\circ$  while carrying loads reported in 1994–1995 was still significantly associated with severe shoulder pain in 2006 after adjustment for the same confounding factors as in the previous analyses, and additional adjustment for date of retirement [adjusted odds ratio ( $OR_{adj}$ ) 3.53, 95% confidence interval (95% CI) 1.01–12.42], but no dose–response relationship was observed anymore.

In analyses restricted to men who did not report any shoulder pain in 1994–1995 (N=1134), the  $OR_{adj}$  for exposure to arm elevation  $>90^\circ$  while carrying loads reported in 1994–1995 was similar (table 3). The influence of work exposure on the persistence (or recurrence) of shoulder pain among workers with shoulder pain at baseline is shown in table 4.

## Discussion

Assessed at baseline, shoulder biomechanical exposure in working life, more precisely exposure to arm elevation  $>90^\circ$  while carrying loads, was associated with severe shoulder pain in this study among men, taking

into account personal confounders (age, BMI, history of shoulder trauma). This association was weaker 12 years later but remained statistically significant. Analyses restricted to men without pain at baseline showed similar results.

Selection effects must be discussed. No statistical difference in severe (or moderate) shoulder pain at baseline was observed between the follow-up and the drop-out groups, even though the lifetime prevalence of exposure to biomechanical factors was only slightly higher in the follow-up group (low magnitude of difference) (14). Selection effects at inclusion and attrition during the follow-up have been studied previously in the GAZEL cohort: the initial participation of men in the whole GAZEL cohort was mostly influenced by lifestyle characteristics such as alcohol consumption, being overweight and health or cultural factors, while dropping out was mostly explained by the occurrence of major health problems (16, 17). Here, the difference in the prevalence of being overweight in the two groups might lead to a potential underestimation of shoulder pain in our final sample. The prevalence of shoulder pain was however similar to the 23.4% prevalence of shoulder symptoms found in a 1-year prospective study among 436 active workers conducted at 12 different worksites (18). It was also similar to the prevalence of shoulder pain in the previous year (22.5%) found in a historical cohort of 1886 men from three occupational groups (machinists, car mechanics and house painters) (19). Overall, even though the drop-out group was slightly different from the follow-up group (less overweight, more exposed to physical factors), the effect on the associations between the risk factors and the outcomes is expected to be minimal. Other potential selection effects could result

**Table 3.** Association between moderate and severe shoulder pain in 2006, and personal and occupational factors assessed in 1994–1995 among workers with no self-reported shoulder pain at baseline [OR<sub>adj</sub>=adjusted odds ratio; 95% CI=95% confidence interval; BMI=body mass index]

	Description								Multinomial logistic model					
	Total		Moderate shoulder pain				Severe shoulder pain				Moderate versus no shoulder pain		Severe versus no shoulder pain	
	N	Mean	SD	Cases (N)	%	Mean	SD	Cases (N)	%	OR <sub>adj</sub>	95% CI	OR <sub>adj</sub>	95% CI	
Age (years)	48.8 <sup>a</sup>	48.8	1.41			48.9	1.30			0.96	0.83–1.11	0.90	0.76–1.06	
BMI (kg/m <sup>2</sup> )	26.0 <sup>b</sup>	26.1	3.27			26.6	2.87			1.02	0.97–1.09	1.08 <sup>c</sup>	1.02–1.15	
Current smoker														
No	898			136	15.14			109	12.14	1.00		1.00		
Yes	236			48	20.34			36	15.25	1.53 <sup>c</sup>	1.03–2.28	1.37	0.87–2.15	
History of shoulder trauma														
No	1028			168	16.34			131	12.74	1.00		1.00		
Yes	106			16	15.09			14	13.21	0.82	0.45–1.52	0.92	0.48–1.77	
Regular sports														
No	796			132	16.58			105	13.19	1.00		1.00		
Yes	338			52	15.38			40	11.83	0.93	0.63–1.35	1.06	0.70–1.62	
Exposed to arm elevation >90° while carrying loads (years)														
<1	902			147	16.30			106	11.75	1.00		1.00		
1–25	186			32	17.20			27	14.52	1.01	0.58–1.73	0.93	0.51–1.70	
≥25	46			5	10.87			12	26.09	0.83	0.21–3.22	4.03 <sup>c</sup>	1.21–13.47	
Exposed to arm elevation >90° without carrying loads (years)														
<1	806			131	16.25			94	11.66	1.00		1.00		
1–25	250			43	17.20			37	14.80	1.27	0.78–2.07	1.50	0.87–2.56	
≥25	78			10	12.82			14	17.95	0.82	0.30–2.21	0.59	0.19–1.83	
Retirement before 1 January 2001														
No	664			113	17.02			76	11.45	1.00		1.00		
Yes	446			67	15.02			69	15.47	0.96	0.63–1.46	1.40	0.87–2.23	

<sup>a</sup> SD=1.39.

<sup>b</sup> SD=3.02.

<sup>c</sup> P<0.05.

from the specificity of the GAZEL cohort. The physical workload in this cohort corresponds mainly to electric distribution maintenance. This physical exposure is different from what can be observed in other activities (the construction industry for instance), probably explaining why exposure to arm elevation >90° without carrying loads was not found to be significant. Workers also kept their job for a long time, with an inter-quartile range of 10–25 years of exposure for most of self-assessed of biomechanical exposures. Hence the variability in exposure was limited. All these elements could explain why there was no clear dose–response relationship, especially in the longitudinal analysis. In addition, the strength of the association probably decreases with time since exposure. Finally, the early age at retirement in the cohort, from 55–65 years old at EDF-GDF, may also have played a role.

The fact that the exposure was self-reported must also be discussed: the authors of a recent review of shoulder disorders and occupational factors stated that in 29% of the selected studies, only questionnaires were used for the assessment of exposure (10). However, the description of the lifetime exposure to physical work-

load in various socioprofessional groups suggested that self-reported exposure was probably accurate, especially “hands above shoulders” and manual handling (20). The validity of lifetime occupational exposure (versus current) is also debatable (21). However, taking into account the stability of the exposure in the cohort, recall bias is probably limited. Regarding the validity of self-reported weight and height, a small but statistically significant underestimation of the BMI (0.29 kg/m<sup>2</sup> on average) has previously been found in the whole GAZEL cohort (22).

Self-reported outcome is the most appropriate measure when studying pain or discomfort. We chose “severe” pain or discomfort as the main outcome, defined by a threshold at the middle of the scale as recommended from guidelines on chronic pain (23). High intensity of pain and presence of disability are closely correlated, especially for patients with symptoms rating over the 50% threshold (14, 23). Shoulder pain can result from different conditions, including rotator cuff syndrome, but we had no information on specific diagnoses. A previous study has found that risk factors of specific shoulder disorders differ from those of subjective complaints

**Table 4.** Association between moderate and severe shoulder pain in 2006, and personal and occupational factors assessed in 1994–1995 among workers with self-reported shoulder pain at baseline [OR<sub>adj</sub>=adjusted odds ratio; 95% CI=95% confidence interval; BMI=body mass index]

	Description								Simple logistic model			
	Total		Moderate shoulder pain				Severe shoulder pain				Severe shoulder pain versus no or moderate shoulder pain	
	N	Mean	SD	Cases (N)	%	Mean	SD	Cases (N)	%	OR <sub>adj</sub>	95% CI	
Age (years)	48.9 <sup>a</sup>	48.8	1.26			48.9	1.30			1.17	0.93–1.46	
BMI (kg/m <sup>2</sup> )	26.6 <sup>b</sup>	26.3	3.03			26.6	3.18			1.03	0.95–1.11	
Current smoker												
No	287			69	24.04			90	31.36	1.00		
Yes	61			13	21.31			22	36.07	0.99	0.52–1.91	
History of shoulder trauma												
No	277			69	24.91			83	29.96	1.00		
Yes	71			13	18.31			29	40.85	1.74	0.96–3.18	
Regular sports												
No	268			64	23.88			82	30.60	1.00		
Yes	80			18	22.50			30	37.50	1.24	0.69–2.23	
Exposed to arm elevation >90° while carrying loads (years)												
<1	244			59	24.18			72	29.51	1.00		
1–25	77			15	19.48			31	40.26	2.25 <sup>c</sup>	1.07–4.70	
≥25	27			8	29.63			9	33.33	1.18	0.37–3.74	
Exposed to arm elevation >90° without carrying loads (years)												
<1	215			50	23.26			69	32.09	1.00		
1–25	100			25	25.00			32	32.00	0.67	0.33–1.38	
≥25	33			7	21.21			11	33.33	1.32	0.45–3.94	
Retirement before 1 January 2001												
No	204			52	25.49			71	34.80	1.00		
Yes	140			29	20.71			40	28.57	0.51	0.28–0.96	
Severe shoulder pain in 1994												
No	127			34	26.77			30	23.62	1.00		
Yes	221			48	21.72			82	37.10	2.52 <sup>c</sup>	1.45–4.39	

<sup>a</sup> SD=1.33.<sup>b</sup> SD=3.15.<sup>c</sup> P<0.05.

without clinical findings (24). However, a recent review has concluded that, for population-based etiological research and surveillance, simple definitions of shoulder disorders should normally suffice considering that complex definitions (eg, involving physical signs, more specific symptom patterns, and investigations) yield similar associations with occupational risk factors (25).

The results were adjusted for age, BMI, smoking, history of trauma, and regular sports considering the suspected role of these factors in shoulder pain or disorders (26, 27). Smoking was found to be associated with shoulder pain. Being overweight is suspected of being associated with shoulder tendinitis: obesity presumably affects the shoulder mainly through impaired metabolism (glucose, lipids, collagen) (27). Being overweight was also found to be associated with shoulder pain in a study on chronic shoulder pain (12). BMI was found to be associated with rotator cuff syndrome in a study of 733 workers (28). In our study, BMI might also be a risk factor for shoulder pain independently from occupational exposure. Shoulder traumatism, one of the most

frequent causes of shoulder pain (29), was also found to be a possible independent risk factor for shoulder pain in our study, but sport, a known risk factor for rotator cuff syndrome, was not significantly associated with severe shoulder pain or discomfort. However, information about sports practice was partial and this variable was mostly used for adjustment purposes. In the 12 years of follow-up, changes in non-occupational exposure might also have occurred. For instance, the subjects may have tried new sports and other leisure activities involving the shoulder, such as gardening. Nevertheless, the level of exposure in these leisure activities is expected to be lower than for occupational factors, as frequently observed in populations of workers (28). It is also probable that in this period of time, no worker had been newly exposed to occupational biomechanical constraints.

After preliminary analyses, we selected “working with arm elevation >90°” (with and without handling loads) to study the long-term effect of biomechanical exposure on the shoulder. It is also one of the known

occupational factors associated with shoulder pain (8–10) especially in association with other constraints (10, 12, 28). Miranda et al (12) carried out a comprehensive national survey among a representative sample (N=7217) of the Finnish adult population in 1977–1980. Twenty years later, the subjects were invited to be re-examined. After excluding those with diagnosed shoulder disorders at baseline, 883 subjects were available for the analyses. Exposure to several physical factors increased the risk further, with an adjusted OR of nearly 3 for  $\geq 2$  exposures. Lifting heavy loads and working in awkward postures were significantly associated with shoulder disorders for women but not for men. The results remained similar after excluding those with any shoulder pain at baseline. The authors concluded that physical workload increases the risk of a subsequent clinical shoulder disorder and that the effects seem to be long-term. A previous population-based study has also reported that physical load factors may have long-lasting effects on shoulder tendinitis in the dominant side (30).

Handling loads alone was too closely correlated with arm elevation  $>90^\circ$  while carrying loads to be studied separately in this cohort. Other occupational biomechanical risk factors (climbing stairs/ladders) could have been chosen for this study. However, considering the specificity of the population, the strong association between exposures, the results of preliminary analyses and the aim of the study, we decided to focus on arm elevation  $>90^\circ$  with and without carrying loads. Repetitiveness and exposure to vibration were not available. Psychosocial factors were not studied given that there is insufficient evidence to conclude a relationship between shoulder disorders and these factors (10, 31)

The main purpose of this study was to analyze the long-term determinants of severe shoulder pain among men, especially the role of arm elevation  $>90^\circ$  while carrying loads. Our results tend to confirm that the factors associated with severe shoulder pain at baseline might be risk factors (or aggravating factors) in the long-term and even after retirement (ie, after cessation of exposure). Even though residual confounding is possible, the present results emphasize the need for surveillance of workers highly exposed to shoulder constraints. In terms of prevention, our findings suggest that losing weight and limiting occupational exposure could be appropriate, especially in view of the persistence of the effect 12 years later, even after retirement. Further studies are needed, conducted in populations including both genders, with more heterogeneity in the exposure to shoulder risk factors and a more precise assessment of past exposure. In future long-term studies, particular attention should be paid to medical diagnoses in order to differentiate pain related to degenerative disorders from pain due to other conditions.

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