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PREDICTIVE FACTORS FOR INCIDENT MUSCULOSKELETAL DISORDERS IN AN IN-PLANT SURVEILLANCE PROGRAM

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ABSTRACT

Objectives: A surveillance program for upper-limb work-related musculoskeletal disorders (UWMSD) based on assessment of health and risk factors was implemented between 1996 and 2000 in a large shoe factory with overall high levels for biomechanical exposure. The study aimed to identify workers with an increased risk of UWMSD incidence.

Methods: In 1996, 1997 and 2000, 166 workers filled out a questionnaire and underwent a standardized physical examination. Factors from the 1996 questionnaire (general, personal and occupational factors) associated with UWMSD incidence in 1997 were selected. The predictive role of these variables was studied with a logistic model, taking into account also gender and age. The performance of a risk score based on this model was studied in 2000, using the Wilcoxon test and ROC curves.

Results: In 1997, 28 incident cases of UWMSD were observed (N=107, 26.2%). Work pace and prior history of UWMSD were the only factors significantly associated with UWMSD incidence in 1997 (respectively 33% versus 13%, p=0.02 and 58% vs 22%, p=0.01). Psychological distress (36% vs 21%, p=0.10), physical fatigue (35% vs 22%, p=0.14), repetitiveness (30% vs 18%, p=0.17), and task precision (33% vs 21% p=0.16) were also included in the logistic model for 1997 UWMSD incidence. Controlling for these variables, prior history of UWMSD remained associated with incidence in 1997 (OR= 5.5, 95%CI 1.4-21.8). In the period from 1997 to 2000, 24 incident cases were observed (N=102, 23.5%). The risk score, based on variables from the 1997 model, was significantly higher for incident cases (median=6 in incident cases vs 4.5 for healthy subjects, p=0.02). ROC curves indicated that the highest agreement reached 67% for sensitivity and 59% for specificity. Among subjects who did not change their task (N=71, 18 incident cases), performance reached 66% for specificity with the same sensitivity.

Conclusion: These results suggest that surveillance programs of UWMSD at a company level are possible even with overall high levels for biomechanical exposure and should take into account occupational and personal factors, including prior history of UWMSD.

Introduction

One dimension of Upper-Limb Work-related Musculoskeletal Disorders (UWMSD) prevention is implementation of surveillance systems. Some authors have proposed a multi-level model for surveillance of UWMSD and their risk factors, such as a first level using questionnaires and checklists, for a rapid assessment, and a second level including clinical examinations and in-depth job analysis by trained health care providers (Scientific committee for musculoskeletal disorders of the ICOH 1996; Hagberg et al. 1995; Ricci et al. 1998). However, very few evaluations of these surveillance system have been performed (Hagberg et al. 1995; Silverstein et al. 1997; Burdorf et al. 1997).

A surveillance program for UWMSD based on assessment of health and risk factors was implemented between 1996 and 2000 in a large shoe factory (Roquelaure et al. 2001; Roquelaure et al. 2002; Roquelaure et al. 2004). This in-plant surveillance program was performed in order to study the ability of various factors to predict incident cases of UWMSD. The factor derived from the incidence of UWMSD in the first year of surveillance were more reliable in predicting the risk of UWMSD in the following three year period than those based on prevalence data or on exposure assessment (Roquelaure et al. 2004). However, these analyses were based on job categories rather than individual data for exposure and other risk factors.

The main purpose in the present study was to complement the previous study of in-plant surveillance with an evaluation of prediction based on individual level data. In order to reach this goal, individual and occupational factors associated with the incidence of UWMSD between 1996 and 1997 were studied. In a next step, a score based on these variables was built and its validity was evaluated on health data from 2000.

Methods

Design

The UWMSD surveillance program implemented in the firm between 1996 and 2000 has been described in previous papers (Roquelaure et al. 2001; Roquelaure et al. 2002; Roquelaure et al. 2004). In 1996, workers were examined by the occupational physician in charge of health surveillance in this company and completed a questionnaire about their working conditions. Workers were examined again by the same occupational physician in 1997 and in 2000.

Population

Six of the twelve production units of the shoe factory, employing about 2,000 workers, were randomly selected and 20% of the blue-collar workers from each of these production units were randomly selected using the payroll rosters. In 1996, 253 blue-collar workers were included in the study and 191 of them were re-examined in 1997. At the second follow-up in 2000, 166 of the 191 workers examined both in 1996 and 1997 were examined again. Our study population comprised these 166 workers.

Personal and exposure factors

Personal and exposure factors were assessed by self-administered questionnaire in 1996.

Personal factors were: gender, age in two categories with a threshold at 45 years, present smoker, past history of diabetes mellitus, hypothyroidism, menopause, and obesity (BMI over 30). Psychological status was assessed by the General Health Questionnaire (12 items) (Goldberg et al. 1997). Physical strain and occupational factors (repetitiveness, work pace, force, task precision, awkward postures, local mechanical stress, vibration exposure, psychological distress

and physical fatigue) were self-assessed using a 6-point scale (appendix 1) ranging from very low (=0) to very high (=5) for each factor [except for vibration assessed on a 5-point scale, ranging from never (=0) to all the time (=4)]. They were divided into two categories: high level/ low level with a threshold at 3 (>3 versus ≤3). Job changes between 1996 and 2000 were also recorded.

Health Outcomes

All the workers were interviewed during the annual compulsory medical visit (1996, 1997 and 2000), and were examined using the same procedure using a structure examination by the same occupational physician in the course of its normal work activity (Roquelaure et al. 2001; Roquelaure et al. 2002; Roquelaure et al. 2004). In the present paper, the health outcome considered was having at least one of the nine UWMSD under review, i.e., tension neck syndrome, rotator cuff syndrome, lateral epicondylitis, medial epicondylitis, cubital tunnel syndrome, radial tunnel syndrome, carpal tunnel syndrome, Guyon's Tunnel syndrome and hand-wrist tendonitis.

Incident cases in the 1996-1997 period were defined as workers with at least one UWMSD in 1997 without any disorder in 1996; for the 1997-2000 period, incident cases were workers with at least one UWMSD in 2000 without any disorder in 1997. Prior history of UWMSD was based only on interview made by the occupational physician in 1996 for the analyses of factors associated with incidence in the 1996-1997 period. For the analyses dealing with incidence in 1997-2000, prior history of UWMSD was defined as at least one UWMSD in 1996, without any disorder in 1997.

Statistical Analyses

Statistical Analysis Software was used for all analyses (SAS v8.2, SAS institute Inc, Mary, NC, USA).

Associations between risk factors in 1996 and 1996-1997 incidence were studied by bivariate analyses (Chi² and Fisher exact tests). In a next step, associations were described with a logistic model controlling for age and gender, with a P level at 0.20 for keeping a variable in the model. A risk score quantifying the probability to be an incident case was built from the model. The score was defined for one worker as:

Risk score= $k\sum_{i=1}^{n} Log(ORi)$

with n equal to the number of the variables in the model (n=8) and ORi the Odds ratio corresponding to the variable i. The constant k, taken here $k=(0,3)^{-1}$, was added in order to get scores closer to integer values.

In 2000, bivariate and multivariate analyses using similar methods were performed using the 1996 exposure items. A logistic model was built also for the subsample of subjects who did not change their task. The performance of the risk score described above was analysed in 2000: ranks based on this score among the 1997-2000 UWMSD incident cases were compared with ranks among the 1997-2000 UWMSD non incident cases, using the Wilcoxon test. Sensitivity and specificity were also studied using receiver operating characteristic (ROC) curves (Goodenough et al. 1974).

Results

Between 1996 and 2000, 166 workers could be followed. Among them, 65 were men (39%); the

mean age was 40.6 years [range 23-53], and the mean number of years at job was 15.2 years in 1996 [range 0-35]. The study population and the comparison between those lost to follow up and the rest of the sample were described in previous papers (Roquelaure et al. 2001; Roquelaure et al. 2002; Roquelaure et al. 2004). A comparison between these two groups is presented in table 1. High exposure to repetitiveness was the only variable which differed between the two groups, but it was less frequent for the workers lost to follow up.

Incidence rate of carpal tunnel syndrome was 14% between 1996-97 and 13% between 1997-2000, rotator cuff syndrome 8% and 7% respectively, lateral epicondylitis 3% and 7%. Incidence rates for the other nine disorders were lower than 5% in both periods.

Table 2 summarizes factors associated in bivariate analyses with UWMSD incidence between 1996 and 1997 (analyses based on 107 workers since 59 suffered from at least one UWMSD in 1996). In 1997, 28 incident cases of UWMSD were observed (26.2%). Work pace and prior history of UMSD were the only factors significantly associated with 1996-1997 UWMSD incidence. Psychological distress, physical fatigue, repetitiveness, and task precision were also kept for the logistic model considering a P level at 0.20. Gender and age were also included. In this model, only prior history of UWMSD remained significantly associated with 1996-1997 UWMSD incidence (table 4). In 2000, 24 incident cases since 1997, among the 102 workers free from disorders in 1997, were observed (23.5%). A similar procedure (bivariate and multivariate analyses using the same variables) was performed on 1997-2000 UWMSD incidence: only psychological distress and prior history of UWMSD were associated with 1997-2000 UWMSD incidence (table 3). Only prior history of UWMSD remained significantly associated with 1997-2000 UWMSD incidence in multivariate analysis of the whole sample (table 4). However, similar analysis restricted to workers who did not change their task showed that psychological distress

was also associated with incidence (elevated OR but limit for significance, table 4).

The risk score from the 1996-1997 model, which is presented in table 5, was significantly higher for incident cases (median=6 in incident cases versus 4.5 for healthy subjects, p=0.02). ROC curves indicated that the highest agreement reached 67% of sensitivity and 59% of specificity, corresponding to 85% of negative predictive value but 33% on positive predictive value (risk score at 5.25, Fig. 1). Among the subjects who did not change their task (N=71 with 18 incident cases, 25.4%), performance reached 66% for specificity with 67% of sensitivity, 85% of negative predictive value and 40% on positive predictive value for the same threshold. Areas under curves were respectively 0.69 and 0.73. In the purpose of surveillance, the risk score performance could be considered as rather good.

Discussion

This study suggests that it is possible to build an individual risk model to identify workers with an elevated risk of UWMSD, even in the setting of high physical exposures. Prior studies of this plant showed no large association between mechanical exposures among workers and elevated prevalence and incidence of UWMSD (Roquelaure et al. 2001; Roquelaure et al. 2002; Roquelaure et al. 2004). The low variation in mechanical exposures between workers make it difficult to identify predictive factors of UWMSD, where usual risk factors (repetitiveness, work pace, task precision, force, awkward postures …) could not be considered as discriminating factors. Actually, some known risk factors for UWMSD were found in our study, such as repetitiveness, work pace and task precision (Bernard BP 1997; Hagberg et al. 1995). However, none of these factors were significantly associated with UWMSD incidence, with fluctuant ORs in the two study periods. Some other known risk factors, such as force and awkward posture, and individual factors, were not associated at all with UWMSD incidence. In addition to the low

variability in exposures between workers, this might be due to low statistical power of the study with a large fluctuation of the odds ratios and the components of the risk score or the heterogeneous aspect of UWMSD, since all UWMSD do not have the same risk factors (Hagberg et al. 1995; Bernard BP 1997; Leclerc et al. 1998; Fredriksson et al. 1999). A score based on factors from the literature on large surveys on UWMSD could be theoretically more stable, but less discriminative considering low contrast in levels of exposure.

Self-assessment of exposure is also a limitation considering the possibility of a lack of precision for risk factor assessment (Heinrich et al. 2004; Li and Buckle 1999). However, there is no consensus about the best methods for exposure evaluation (Stock et al. 2005; Leclerc 2005), and the optimal exposure assessment methods are probably different for different types of studies including surveillance (Hagberg et al. 1995). Previous work on the 1996-1997's data from this company showed that self-reported exposures via questionnaire may be more accurate than observational methods in identifying subjects at high risk for UWMSD (Descatha et al. 2006). The risk score described above was thus adapted to one specific plant, with overall high levels for biomechanical exposure.

The study period was a potential source of limitation. Jobs changes could have occurred in the four years of the study period. However, worker turn over was low (Roquelaure et al. 2002; Roquelaure et al. 2004). In four years, only 30% of the workers without any UWMSD (n=32), declared that their tasks had changed. The risk score was evaluated according to presence or absence of a disorder 3 years later, which is a long period of time: UWMSD could occur and be cured between 1997 and 2000. For instance, in a similar population, exposed to high level of repetitiveness, the recovery rate of medial elbow disorders (medial epicondylitis and ulnar nerve

entrapment at the elbow) was over 80% in a three year period (Descatha et al. 2003; Descatha et al. 2004). However, the only variable significantly associated with 1996-1997 UWMSD incidence in the logistic model (ie prior history of UWMSD) was also associated with UWMSD incidence between 1997 and 2000, and variables not significantly associated with incidence in the 1996-1996 period were not either significantly associated with incidence in the1997-2000 period.

Selection effects must be discussed considering the 34% of workers lost to follow up. However, the major cause of loss to follow up was economical reasons, and the selection for health reasons between the three physical examinations was minimal during the four-year follow up period (Roquelaure et al. 2004). Furthermore, the only difference between those lost to follow up and the rest of the sample in 1996 was that those lost to follow up had a lower level of repetitiveness. These elements implied probable low selection effects from lost to follow up. Healthy worker effect could also been discussed, considering the elevated age of workers (34% older than 45 years old). Although the mean age was similar to other studies in the clothing and shoe industry (Kaergaard and Andersen 2000; Li et al. 1995), workers in our cohort had a very high number of years on the job.

The very high proportion of workers with prior UWMSD confirmed the recurrent aspect of these disorders, and was a reason to consider prior UWMSD as a specific risk factor. It could has been considered as overadjustment. However, in a model without this variable the associations between the other risk factors and incidence were not changed. A prospective study among 598 workers exposed to repetitive work also found that prior history of one UWMSD was associated with incidence of ulnar nerve entrapment at the elbow (Descatha et al. 2004). Fredriksson et al. found that neck symptoms earlier in life were associated with recurrent disorders in a large range

of occupations study (Fredriksson et al. 1999).

Conclusions

In conclusion, this study suggests that surveillance programs of UWMSD at company level should take into account occupational and personal factors at an individual level. Prior history of UWMSD is an important element in surveillance programs in high exposures settings.

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	Workers lost to follow up		Workers in the study		
	Frequency	**%**	**Frequency**	**%**	**p=**
Gender: men	28	*32.2*	65	*39.2*	0.27
Age : ≥ 45 years	24	*27.6*	56	*33.7*	0.32
Present smoker	13	*15.0*	30	*18.1*	0.53
Past history of diabetes mellitus or hypothyroidism or menopause	8	*9.2*	12	*7.2*	0.58
Obesity (body mass index ≥30)	5	*5.8*	16	*9.6*	0.29
GHQ12 ≥ 18.5	9	*14.5*	15	*10.3*	0.38
Psychological distress	30	*34.5*	55	*33.1*	0.82
Physical fatigue	24	*27.6*	55	*33.1*	0.37
Repetitiveness	48	*55.2*	115	*69.3*	**0.03***
Work pace	47	*54.0*	109	*65.7*	0.07
Force	25	*28.7*	51	*30.7*	0.74
Task precision	34	*39.1*	80	*48.2*	0.17
Awkward postures	17	*19.5*	39	*23.5*	0.47
Local mechanical stress	18	*20.7*	49	*29.5*	0.13
Vibration exposure	2	*2.3*	12	*7.2*	0.14
Prior history of UWMSD en 1996	23	*26.4*	35	*21.1*	0.34
UWMSD diagnosed in 1996	30	*34.5*	59	*35.5*	0.87
Total	**87**	***34.4***	**166**	***66.6***	

Table 1 : Comparison of 1996 variables for lost to follow up workers and workers in the study
GHQ12= 12 items General Health Questionnaire, UWMSD = upper-limb work-related musculoskeletal disorders

Risk factors in 1996		Incidence of UWMSD, 1996-1997			
		N [1]	Number of cases	Incidence (%)	p=*
Gender	*Women*	63	15	23.8	0.51
	Men	44	13	29.6	
Age	*<45 years*	74	17	23.0	0.26
	≥45 years	33	11	33.3	
Present smoker	*No*	86	24	27..9	0.41
	Yes	21	4	19.1	
Past history of diabetes mellitus or hypothyroidism or menopause	*No*	100	25	25.0	0.38
	Yes	7	3	42.9	
Obesity (body mass index ≥30)	*No*	99	25	25.3	0.43
	Yes	8	3	37.5	
GHQ12	<18.5	86	23	26.7	0.46
	≥18.5	10	4	40.0	
Psychological distress	*No*	71	15	21.1	0.10
	Yes	36	13	36.1	
Physical fatigue	*No*	73	16	21.9	0.14
	Yes	34	12	35.3	
Repetitiveness	*No*	34	6	17.7	0.17
	Yes	73	22	30.1	
Work pace	*No*	38	5	13.2	**0.02**
	Yes	69	23	33.3	
Force	*No*	82	22	26.8	0.78
	Yes	25	6	24.0	
Task precision	*No*	58	12	20.7	0.16
	Yes	49	16	32.7	
Awkward postures	*No*	80	19	23.8	0.33
	Yes	27	9	33.3	
Local mechanical stress	*No*	78	18	23.1	0.23
	Yes	29	10	34.5	
Vibration exposure	*No*	101	27	26.7	1.00
	Yes	6	1	16.7	
Prior history of UWMSD	*No*	95	21	22.1	**0.01**
	Yes	12	7	58.3	
Total		**107** [1]	**28**	**26.2**	

Table 2: Associations between occupational and personal factors (assessed in 1996) and upper-limb work-related musculoskeletal disorders (UWMSD) incidence between 1996 and 1997.
** = Chi² and/or Fisher exact tests [1]= Number of worker without any UWMSD in 1996*

Risk factors in 1996		Incidence of UWMSD, 1997-2000			
		N[1]	Number of cases	Incidence in 3yrs (%)	p=*
Gender	*Women*	63	15	23.8	0.93
	Men	39	9	23.1	
Age	*<45 years*	71	16	22.5	0.72
	≥45 years	31	8	25.8	
Present smoker	*No*	81	14	22.6	0.39
	Yes	21	3	14.3	
Past history of diabetes mellitus or hypothyroidism or menopause	*No*	97	22	22.7	0.34
	Yes	5	2	40.0	
Obesity (body mass index ≥30)	*No*	96	22	22.9	0.56
	Yes	6	2	33.3	
GHQ12	<18.5	83	19	22.9	0.66
	≥18.5	7	2	28.6	
Psychological distress	*No*	72	13	18.1	0.04
	Yes	30	11	36.7	
Physical fatigue	*No*	71	14	19.7	0.17
	Yes	31	10	32.3	
Repetitiveness	*No*	34	5	14.7	0.14
	Yes	68	19	27.9	
Work pace	*No*	40	6	15.0	0.10
	Yes	62	18	29.0	
Force	*No*	73	14	19.2	0.10
	Yes	29	10	34.5	
Task precision	*No*	54	12	22.2	0.74
	Yes	48	12	25.0	
Awkward postures	*No*	80	19	23.8	0.92
	Yes	22	5	22.7	
Local mechanical stress	*No*	76	18	23.7	0.95
	Yes	26	6	23.1	
Vibration exposure	*No*	94	22	23.4	1
	Yes	8	2	25.0	
Prior history of UWMSD	*No*	79	14	17.7	**0.01**
	Yes	23	10	43.5	
Total		**102**	**24**	**23.5**	

Table 3: Associations between occupational and personal factors (assessed in 1996) and upper-limb work-related musculoskeletal disorders (UWMSD) incidence between 1997 and 2000.
** = Chi² and/or Fisher exact tests, [1]= Number of worker without any UWMSD in 1997*

		UWMSD 1996-1997		UWMSD 1997-2000 **		UWMSD 1997-2000 ***	
		OR [95% CI]	**p=**	**OR [95% CI]**	**p=**	**OR [CI95%]**	**p=**
Gender	*Women*	1	0.28	1	0.95	1	0.99
	Men	1.72 [0.65-4.60]		0.97 [0.34-2.78]		1.00 [0.27-3.77]	
Age	*< 45 years*	1	0.37	1	0.93	1	0.75
	≥ 45 years	1.59 [0.58-4.38]		1.05 [0.35-3.13]		0.81 [0.22-2.93]	
Psychological distress	*No*	1	0.62	1	0.14	**1**	**0.05**
	Yes	1.37 [0.40-4.77]		2.46 [0.74-8.16]		**4.49 [1.00-20.01]**	
Physical fatigue	*No*	1	0.82	1	0.92	1	0.91
	Yes	0.86 [0.24-3.15]		0.94 [0.27-3.32]		0.92 [0.20-4.30]	
Repetitiveness	*No*	1	0.61	1	0.77	1	0.82
	Yes	0.67 [0.14-3.18]		1.25 [0.27-5.83]		1.27 [0.16-9.79]	
Work pace	*No*	1	0.10	1	0.55	1	0.83
	Yes	3.73 [0.77-18.04]		1.56 [0.36-6.85]		1.23 [0.18-8.52]	
Task precision	*No*	1	0.17	1	0.47	1	0.83
	Yes	2.05 [0.73-5.80]		0.67 [0.23-1.95]		0.86 [0.23-3.26]	
Prior UWMSD*	*No*	**1**	**0.02**	**1**	**0.01**	**1**	**<0.01**
	Yes	**5.47 [1.37-21.75]**		**3.90 [1.31-11.62]**		**7.00 [1.64-29.87]**	
TOTAL		**N=28/107**		**N=24/102**		**N=18/71**	

Table 4: Mutivariate analyses (logistic models) for upper-limb work-related musculoskeletal disorders (UWMSD) incidence in the 1996-1997 and 1997-2000 periods.
Variables in the model were selected from bivariate analyses of 1996-1997 UWMSD incidence (P level at 0.20 plus gender and age)
**=for the first period, prior history of UWMSD before 1996, according to the interview in 1996; for the second period, UWMSD diagnosed in the physical examination in 1996 (and not found in 1997)*
***= All subjects included (without any disorder at baseline)*
****= Restricted to workers who did not changed their task*

VARIABLE	OR	Log OR (=bêta)	k x Log OR *
Score	**-**	**-**	**0**
Men	1.72	0.54	**+2**
Age ≥ 45 years	1.59	0.47	**+1.5**
Physical fatigue	0.86	-0.15	**-0.5**
Psychological distress	1.37	0.32	**+1**
Repetitiveness	0.67	-0.40	**-1.5**
Work pace	3.73	1.32	**+4.5**
Task precision	2.05	0.72	**+2.5**
Prior history of UWMSD	5.47	1.70	**+6**

Table 5: Components of the risk score issued from the on 1996-1997 upper-limb work-related musculoskeletal disorders (UWMSD) incidence model.
* rounded

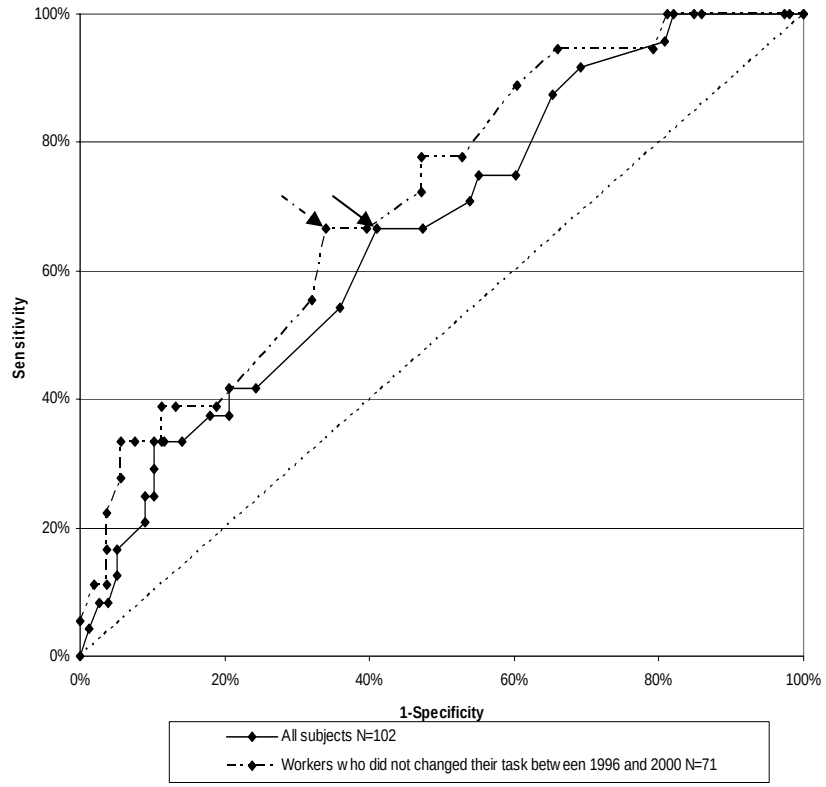

Figure 1: Receiver operative characteristics (ROC) curves based on risk score for upper-limb work-related musculoskeletal disorders (UWMSD) incidence between 1997 and 2000 (among worker without UWMSD in 1997).

The arrows indicated the optimal threshold (all subjects: sensitivity 67% and specificity 59%; workers who did not change their task: sensitivity 67% and specificity 66%).

A sensitivity equal to 100% would indicate that all the workers suffering from one UWMSD would have been correctly classified by the risk score (no false negative cases) and a specificity of 100% that all workers without any UWMSD would have been correctly classified (no false positive cases).

Appendix 1: Questions about physical strain and occupational factors.

Do you think your work is repetitive? (**repetitiveness**)
Not at all → / 0 / 1 / 2 / 3 / 4 / 5 / extremely
Is work pace: (**work pace**)
Slow → / 0 / 1 / 2 / 3 / 4 / 5 / very fast
The force needed in your work is? (**force**)
Very low → / 0 / 1 / 2 / 3 / 4 / 5 / very high
In your work, do you have precision tasks? (**task precision**)
Never → / 0 / 1 / 2 / 3 / 4 / 5 / always
In your work, have you awkward posture? (**awkward posture**)
Never → / 0 / 1 / 2 / 3 / 4 / 5 / always
In your work, have you to press tight objects in your hand or between your thumb and your index? (**local mechanical stress**)
Never → / 0 / 1 / 2 / 3 / 4 / 5 / always
Are you exposed to vibrations (**vibrations**)
Not at all → / 0 / 1 / 2 / 3 / 4 /extremely
Do you think you work is physically tiring? (**physical fatigue**)
Not at all → / 0 / 1 / 2 / 3 / 4 / 5 / extremely
Do you think you work is psychologically tiring? (**psychological distress**)
Not at all → / 0 / 1 / 2 / 3 / 4 / 5 / extremely