Prevention of upper extremity disorders due to biomechanical overload in the sofa industry

S. Nicoletti[a], M. Carino[b], G. Di Leone[c], G. Trani[c],
D. Lagravinese[c], N. Battevi[d], D. Colombini[d], E. Occhipinti[d]

[a] *School of Occupational Medicine University of Foggia, Italy,*
[b] *IRCCS Salvatore Maugeri Foundation Cassano M. (Bari), Italy,*
[c] *Department of Prevention-SPESAL AUSL Bari/3 Regione Puglia, Italy,*
[d] *IRCCS Policlinico-Mangiagalli Foundation, EPM - CEMOC, Milan, Italy*

Abstract

A total workforce of 5776 individuals (M=4005, F=1771, exposed n=3455 and controls n=2321) in thirty plants of the upholstered manufacturing industry in a large geographical area of Southern Italy was examined by a network of occupational health physicians over a 4-year period (2000-2003). More than 60 percent of the workforce studied was within large size companies (>500 employees). Exposed groups included: frame outfitters, leather-cutting operators, seamstresses and upholstery-assembly workers. Case-definition of upper extremity disorders was assessed through standardized procedures: symptoms by questionnaire plus physical and laboratory/imaging findings. Annual incidence rates of work-related upper limb musculo-skeletal disorders ranged 1-6% and cumulative prevalence rates of WMSDs at December 2003 reached maximum values exceeding 20% in high-risk groups. Exposure assessment to repetitive strain and movements of the upper limb was performed in a representative sample of the plants using the OCRA index and showed average values ranging 2-15 for different exposed groups. The OCRA method showed good correlation both with the case-prevalence and incidence rates. Most frequently occurring disorders were tendon-related cysts and wrist tendinitis. The shoulder disorders were most represented in male and female leather-cutting operators. (Supported by grant BS11-03 from Italian Ministry of Health).

Keywords: MSD, sofa industry, risk assessment, prevalence, incidence rate

Upper-extremity musculoskeletal disorder (MSD) appears to be significantly under-reported, and rates are not decreasing over time [1]. According to the Sanitary Program of the Regione Puglia, Italy, the Department of Prevention of the Local Health Authority Bari/3 and the IRCCS Maugeri Foundation of Cassano Murge carried out a 4-year survey (2000-2003) in cooperation with the Center of Occupational Medicine CEMOC-EPM, Milan in a sofa production district located in a large geographical area of Southern Italy. The study was supported with funds from Italian Ministry of Health and data were collected by a network of occupational health physicians[(a)]. More than 65 percent of the workforce studied was within large size firms (>500 employees).

Our study was undertaken to accomplish the following: risk assessment of upper extremity biomechanical overload in the upholstered manufacturing industry, analysis of prevalence and incidence rates of upper limb musculoskeletal disorders, evaluation of proposed interventions of single company and sharing in the whole production district of the most effective ergonomic strategies. In this paper the production cycle, risk assessment and epidemiological survey data are reported. In a different paper ergonomic proposed intervention of large companies are discussed.

1) The production cycle in the upholstered manufacturing industry

The productive cycle of the sofa begins with the production of the frame made of wood (or with other materials such as masonite). This single activity is carried out from appropriate plants that supply the sofa district. Another productive line also carried out from external plants supplies padding in expanded polyurethane (EPU). Pieces of EPU, in various shape and consistency, are assembled in order to realize the different parts of the padding and are manufactured in a

single pack for each model (including pillows and the softer parts of the padding).
webbing, every single strap is fixed to one extremity of the bottom or of the back of the frame, it is pulled manually and at the same time is fixed to the other extremity. In some plants the semi-automatic webbing is also present, reducing around 50% of the activity of manual traction of the straps. Therefore the webbing operator carries out the tasks of frame handling (before and after the webbing), stapling (with appropriate compressed air tool with metallic points) and manual traction of the straps. The duration of a cycle varies between 1 and 8 minutes (average: 2.5 min.).

The webbed frames and packs with padding meet on the table of the frame outfitter that sticks the EPU padding on the frame. Typical tasks of the frame outfitter are: frame handling (before and after that the EPU has been fixed), EPU handling, distribution of the glue with spray-gun on the frame and on other pieces of EPU, application of single pieces of EPU that is fixed to the frame also with pressure of the hands. The duration of a preparation-outfitting cycle can vary (based on complexity of the sofa model) between 4 and 20 minutes, with an average of approximately 8 min. In most plants the two task jobs are unified (webbing operator/frame outfitter) and it is frequent that the same operator has carried out both tasks in his working history or he may have stepped from one to the other task based on the various productive and organizational needs.

Another production line supplies the sofa covering. For the models in textile or microfiber material, the cut of single pieces is carried out with appropriate automatic cutting set. A similar activity located close to the textile cutting is carried out for the preparation of the linings from the automatic cutting and the linings matching operators. For leather sofa, the job is still today mostly manual in all the plants: the leather cutter captures the single hide from a support close to his own workstation, spreads it on the cut table (hide handling, color check and verification of raw side) than he checks all the hide in order to identify any natural marking.

This phase of search of the natural markings implicates that the leather is ironed with the hands (in order to be able to estimate the characteristics) and the strain practiced from the operator depends upon thickness of the raw materials (soft skin, thick skin, crust) and from the qualitative level of the final product. Then the operator puts in the correct position the shape-support (made of masonite or of plastic material) on the hide. This is the more delicate phase of the leather cutting because determines the quality of the final product and regulates the consumption of expensive raw materials.

Then the leather cutting is made with one simple manual tool with vertical blade: the necessary exertion to this task is once again function of the thickness and the hardness of the skin. Finally, cut pieces are folded according to the following use in the production cycle and they are arranged in a box. The average life of the

The webbing operators apply elastic straps on the frame in order to support the padding; in the manual cutting cycle of one leather hide is approximately 22 min, with a 20-25 min. range.

The cut material (textile or leather) is then processed by the seamstresses in order to produce the definitive covering: this part of the cycle is made of separated phases that can be carried out from one single operator, or can be carried out in distinguished tasks. In this case the passage from one task to the others is made by the same (usually female) operator. The duration of a seam cycle is extremely variable, average time 50-60 min., range 30 -120 min. The decking sewing implicates low strain. Single pieces of lining are assembled: the small size of pieces, the reduced weight and the low thickness of the material to be sewed make an easy task (duration 3-8 min; average time 4 min., 8-10 % of total cycle). In the sewing of pieces (back, pillow) the single fragments of textile or microfiber or leather are assembled together in order to make part of covering (duration 12-30 min., average 20 min., 35-40 % of the total cycle time).

Subsequently the 'pieces' go to the special procedures (straight stitching and curly stitching) necessary to guarantee an aesthetic effect of the single covering (each of the two can engage the operator for 4-15 min, according to the models, average time 7 min., 8-12 % of the total cycle time). Finally pieces return to the machine of smooth sewing for final sewing that realizes only one covering or a reduced number of covering parts, that will be then used as such from the upholsterer (duration 10-30 min.; average 17 min., 20-25 % of the total time of cycle).

In all this phases, the effort of the operators depends on softness and thickness of the covering to be sewed (with one increasing progression from the woven to the microfiber, to soft leather, the thick leather until the crust) and from the complexity of the sofa model. As the covering is made up, volume and weight increase and also the strain necessary to complete the job increases (respectively from a simple puff, to one seat, to a two or three places sofa). Beyond the described tasks the seamstresses also handle the box containing at the beginning single pieces to be sewed and at the end the complete covering. The weight of the box can vary from 5 to 20 Kg (rarely 30 Kg). Seamstresses also handle single pieces, set for the following seam; these tasks last 10-20 % of the time of total cycle.

The frame covered with EPU and with covering, converges finally to the worksite of the upholsterer (= assembler) that performs the final phase of cycle: dressing the frame with the covering, filling up backs or pillows with the padding, completing the assemblage of single parts, and, if requested, mounting accessories (nets for the sofa-bed, recliner mechanisms, etc). All the single parts are captured from the only undercarriage on which they are crammed and progressively set on the worktable (handling of heavy pieces like the stalk or the back and handling of light pieces such as single pillows or single parts of the covering).

Subsequently all the covering parts must be filled up with the respective padding that can be made of light ribbon, soft rubber or hard rubber. Obviously the strain necessary for cushion filling is related to the consistency of the padding material. As the job proceeds, is necessary to carry out other tasks: to fix single pieces of EPU in particular positions in the same way used by frame outfitter (to spray glue with spray-gun), to block various parts of the wood frame to the body (armrest or back espalier or recliner mechanisms), to screw with compressed air tools and to fix the covering on the frame with metallic points (compressed air stapling).

Finally the upholsterer/assembler performs the actual 'dressing up', when the covering is progressively forced on the padding, until covering it all, for being definitively fixed to the base. The given description of several tasks does not have to be interpreted in a temporal sense, since the same upholsterer goes from one task to the other continuously. The duration of the cycle is 15-150 min. with average time 25-35 min.

In order to complete the description of the task jobs involved in the productive cycle, the 'indirect workers' that participate to the productive cycle must be cited. They are the responsible warehousemen of raw materials and of the final product warehouse, the operators that feed single emplacements or that manage all the intermediate handling, the unit heads, operators deputed to quality control, the cleaners of finished product, packing and maintenance workers. For those groups, because of the remarkable mobility of the workers between the various emplacements and the remarkable differences between the various companies, is not possible to characterize homogenous task jobs. For these reasons those workers were enrolled in the worker control group for the OCRA index and epidemiological data analysis.

2) Workforce population

The working population studied is described in Tab 1. For workers employed in the years in different companies but with the same task job, the working seniority has been calculated from the date of the first enrolment in any company of the production district. In the three largest companies (>500 employees) the voluntary drop out rate per year was 4.1%, with a further annual 8,2 % because of the leaving off the job relationship or for an unsuccessful test-period. Therefore the total drop out per year was 12.3% (period of reference 1999-2004, denominator: mean workforce population of the period). The absence due to pregnancy was estimated in the period 2000-2004. In the same three large companies on a total of 794725 effective work-days there was a 'lost' of 107117 days (13,5 %) for absence from work due to pregnancy.

More than 60 percent of the workforce studied was within large size companies (>500 employees, Tab. 2).

Tab. 1: Characteristics of the study population

task job	M	F	M+F	age (y)	duration of exposure (y)
upholstery workers	973	0	973	29,6	6,6
frame outfitters	309	4	313	32,0	7,6
seamstresses	13	1289	1302	30,0	8 (6,9*)
cutting operators	595	90	685	29,4	6,0
carpenters	182	0	182	34,2	10,0
worker controls	1402	196	1598	35,2	8,7
blue collar controls	531	192	723	35,4	7,8
total employees	4005	1771	5776	32,9	7,7
* adjusted for absence due to pregnancy					

Tab. 2: characteristics of the plants

plant size (employees)	< 50	51- 100	101- 500	> 500
number of plants	19	6	4	1
total employees	423	437	1044	3621

3) Methods

The OCRA method was used for assessing exposure to repetitive strain and movements of the upper limb [2]. For the clinical survey all the data have been collected from individual medical records. The instrumental diagnostic assessments were not centralized because of the large geographical area of the district and therefore they have been carried out in different medical facilities, normalizing for inter-observers bias. For case definition the following criteria were adopted:

a) Shoulder diseases, lateral and medial epicondylitis, wrist-hand tendinitis and tendon-related cysts have been documented at least through diagnostic ultrasound examinations. Magnetic resonance (MR) or computed tomography (CT) imaging were also considered if available.

b) Carpal Tunnel Syndrome was assessed through electrodiagnostic study. It was considered abnormal if a $\geq$ 2 SD reduction of conduction velocity of the electromyographic (EMG) evaluation or of the motor/sensory nerve conduction velocities (MCV/SCV) was present. Adequate consideration in many cases was given to diagnostic ultrasound examinations documenting a simultaneous tendon-related disorder.

The following epidemiological indicators were used:

a) Incidence (onset of new cases per year) in the period 2000-2003, new case = worker affected for the first time by at least one disorder during a year-around frame time.

New cases annual incidence rate (I) =number of new cases x 100/ workforce at Dec 31st of each year

b) New cases mean annual incidence rate = arithmetic mean of new cases annual incidence rates in a four-year term

New cases mean annual incidence rate in 2000-03 (MAI) = total number of new cases in 2000-03 / 4 x 100 / mean working population in 2000- 03

c) Prevalence: % of cases at Dec 31 2003, case = worker who got at least a disorder during his working history, with actual job activity.

Cumulative prevalence rate (P) = n. of cases x 100)/ total number of subjects at Dec 31st 2003.

4) Results

The OCRA index analysis according to main organizational variables influencing the same index such as task job, size of the plant and number of structured pauses during the working day are reported in table 3. To the control group it has been attributed an OCRA value of 2,2 that is a borderline value between absence of exposure and an uncertain or very light exposure [3][4].

Tab. 4 summarizes the results of the clinical survey in the total population studied, with gender differentiation.

Tab. 3: OCRA Index values according to task job and plant characteristics

task job	plant characteristics			total n. of subjects (2000-03)	**OCRA index**		
	size (n. of empoyees)	workday pauses	number of plants		**employee - adjusted mean**	min	max
upholstery workers	< 100	1	4	47,5	**13,7**	11,3	14,6
		2	15	74,5	**10,3**	8,5	11,0
		3	6	30	**9,5**	7,8	10,1
	100-500	1	2	70,8	**12,8**	10,4	15,2
		2	2	84,3	**9,6**	7,8	11,4
	> 500	1	1	583	**10,9**	10,9	10,9
frame outfitter	< 100	1	4	17	**7,7**	6,3	8,2
		2	15	31,1	**5,8**	4,7	6,1
		3	6	12,8	**5,3**	4,4	5,7
	100-500	1	2	53,3	**7,4**	6,1	8,8
		2	2	35,8	**5,6**	4,6	6,6
	> 500	1	1	142	**7,7**	7,7	7,7
cutting operators	< 100	1	4	41,5	**9,9**	8,2	10,6
		2	15	78	**7,4**	6,1	7,9
		3	6	30,8	**6,9**	5,7	7,3
	100-500	1	2	37,1	**8,7**	7,1	10,3
		2	2	37,5	**6,5**	5,3	7,7
	> 500	1	1	358	**8,7**	8,7	8,7
seamstresses	< 100	1	4	69,5	**12,1**	10,0	12,9
		2	15	160	**9,1**	7,5	9,7
		3	6	36,5	**8,4**	6,9	8,9
	100-500	1	2	109	**10,7**	8,7	12,6
		2	2	89,8	**8,0**	6,5	9,5
	> 500	1	1	708	**11,9**	11,9	11,9
worker controls	< 100	1	4	58,5	**2,2**	2,2	2,2
		2	15	152	**2,2**	2,2	2,2
		3	6	63,8	**2,2**	2,2	2,2
	100-500	1	2	164	**2,2**	2,2	2,2
		2	2	141	**2,2**	2,2	2,2
	> 500	1	1	1280	**2,2**	2,2	2,2

Tab. 4: Incidence, mean annual incidence (MAI) and cumulative prevalence (P) of WMSDs in the total population studied

year	M	F	M+F
2000	1,2%	1,6%	1,4%
2001	2,6%	2,3%	2,5%
2002	3,1%	2,3%	2,8%
2003	1,2%	0,9%	1,1%
MAI	2,1%	1,8%	2,0%
P	8,7%	8,1%	8,6%

The annual mean incidence rate in the period 2000-03 and cumulative prevalence rate at Dec 31st 2003 in the various task jobs, differentiated for gender are showed in Tab 5. Correlation analysis between the two epidemiological rates and the OCRA index is reported (it was used the mean value of the OCRA index for each task job, adjusted for the number of the employees of each plant).

Tab. 5. Cumulative prevalence (P), mean annual incidence (MAI), gender, task job and correlation with OCRA index

	task job	n. employees	OCRA index *	MAI	P
M	tot. employees	3236		2,0%	8,5%
	upholstery wkrs	840	10,9	5,5%	22,6%
	frame outfitters	270	7,1	3,1%	12,5%
	leather cutter	502	8,4	2,2%	8,7%
	worker controls	1624	2,2	0,8%	3,6%
	correlation with OCRA index			0,89	0,88
F	tot employees	1427		1,8%	8,1%
	seamstresses	1148	11,0	2,1%	9,4%
	leather cutter	89	8,4	3,5%	15,1%
	worker controls	190	2,2	0,8%	4,4%
	corelation with OCRA index			0,68	0,66
(*) = mean value among all plants adjusted for the number of employees					

Tab. 6: Cumulative prevalence of different WMSDs in single task jobs of the study population.

task job	shoulder diseases	epicondilitis	wrist tendinitis and tendon-cysts	carpal tunnel syndrome	hand tendinitis	others disorders
upholstery wkr	1,9%	5,1%	19,0%	1,8%	1,3%	0,0%
frame outfitter	1,1%	2,5%	7,2%	0,0%	2,9%	0,0%
leather cutter M	1,7%	2,1%	5,6%	0,4%	0,6%	0,0%
leather cutter F	2,2%	2,2%	7,8%	2,2%	0,0%	0,0%
seamstresses	0,8%	1,7%	7,9%	2,9%	0,3%	0,0%
carpenters	0,6%	0,0%	2,2%	0,6%	0,6%	0,0%
wrkrs controls M	0,5%	1,0%	2,0%	0,3%	0,2%	0,0%
wrkrs controls F	0,0%	0,5%	2,6%	0,5%	0,5%	1,0%
tot employees	1,0%	2,1%	7,3%	1,2%	0,6%	0,0%

Cumulative prevalence at December 31, 2003 of single disorders in the total population reached 19.0% values (table 6).

5) Discussion

Even though the female gender is considered a predisposing factor for the onset of WMSDs [3] we observed no significative differences in our cumulative prevalence data. Probably gender differences are important for low-medium levels of exposure, but tend to be less important to increasing level of risk. The analysis of prevalence and OCRA index data would make to think the female gender as a sort of 'protective factor' regarding the risk to become affected.

As far as single task jobs are concerned, it should be emphasized that the general good correlation of prevalence/incidence rates with the OCRA index is slightly reduced by the excess of disorders in the group of the frame outfitters characterized from a greater working seniority and a higher mean value of age. Similarly in the group of seamstresses: they have an equivalent OCRA index to the assembly workers but show very lower prevalence and incidence rates (almost 40-50% in comparison with assemblers).

About single diseases, the greatest prevalence of all disorders was observed in the group of the upholstery workers, except for shoulder disease that has a higher prevalence in the group of the cutters (with no gender-related differences).

The carpal tunnel syndrome instead has a greater prevalence in the two female groups of risk (seamstresses and leather cutters). Probably this is the only disorder that has a gender-related predisposing factor at a same level of exposure. In particular in the single group of seamstresses (near 20% of total workforce) it was observed the 57% of the total amount of carpal tunnel syndrome.

6) Conclusions

This project is a collaborative effort between different institutions of research, universities, territorial departments and numerous privately owned firms. Plants of different size were studied concurring to the possibility of transferring to small firms results from high quality risk assessment, managerial experiences and ergonomic proposed intervention of large companies.

In another paper these strategies will be discussed into details and the initiatives taken in order to implement a set of standards of health and safety at work in the whole upholstered manufacturing industry district will be illustrated.

The task activities analysed in the sofa industry is characterized by very long cycles (between 5 and 60 min, with some of them reaching 150 min). The sequence of the single tasks in the different cycles of production may vary with the sofa model, even all sub-tasks save their own characteristics. A correct application of the OCRA method achieved a concise and accurate assessment of the risk, even though the tasks analysed in the upholstered manufacturing industry were not always very repetitive and stereotyped.

The OCRA index showed good correlation with prevalence and incidence rates. In particular the annual incidence rate, rarely investigated in the literature, showed even a better correlation than prevalence rates. For preventive purposes a reliable risk assessment does not exclude health surveillance programs. Standardized procedures of identification a sudden increase of the incidence of cases of WMSDs may be strategic in facing epidemic onset of the disorders that may occur in some circumstances such as highly intensive production of thick leather sofa.

(a) Occupational Health Physicians Network:
F. Carella S. Colafiglio, E. Leone, R. Popolizio, G. Rubino

References

[1] Morse T, Dillon C, Kenta-Bibi E, Weber J, Diva U, Warren N, Grey M. Trends in work-related musculoskeletal disorder reports by year, type, and industrial sector: a capture-recapture analysis. Am J Ind Med. 2005;48(1):40-49

[2] Occhipinti E. OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. Ergonomics. 1998; 41,9:1290-311.

[3] Occhipinti E. Colombini D. [The OCRA method: updating of reference values and prediction models of occurrence of work-related musculo-skeletal diseases of the upper limbs (UL-WMSDs) in working populations exposed to repetitive movements and exertions of the upper limbs] Med Lav 2004; 95, 4: 305-319.

[4] Colombini D., Occhipinti E. [Results of risk and impairment assessment in groups of workers exposed to repetitive strain and movement of the upper limbs in various sectors of the industry] Med Lav 2004; 95, 3: 233-246.