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Concise Exposure and Damage Indicators for Predicting Foreseeable Effects Of Work-Related Upper Limb Disorders

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Abstract

Since work-related musculoskeletal disorders ($WMSD_S$) have a high prevalence in different industries, in order to quantify the prevalence of $WMSD_S$ of the upper limbs in of exposed group and find a relationship between exposure indices and effect indicators, this research was carried out. A total of 404 male exposed and of 120 male non-exposed workers of Qaemshahre (northern Iran) weaving factory located in the north of Iran were studied. Regarding the quantification of exposure, use was made of the Occupational Repetitive Actions (OCRA). Also the Concise Damage Index (CDI) was calculated for any job and then statistically significant relationships between CDI and OCRA exposure indices were surveyed. It was considered that there were significant associations between OCRA and an effect indicators (CDI) represented by the prevalence of all the $WMSD_S$ of the upper limbs (R^2= 0.85, P=0.001). When a logarithmic conversion of the relative exposure (OCRA) and injury indices was carried out, a simple and multiple linear regression model resulted that seems to provide a satisfactory and truly predictive performance of the risk of $WMSD_S$ of the upper limbs based on the exposure index, length of time, lack of recovery periods, and etc.

Keywords: *CDI, OCRA, $WMSD_S$, Foreseeable effects, Iran*

Introduction

Musculoskeletal disorders is no recent problem (1). Work-related musculoskeletal disorders ($WMSD_s$) is a term given to a group of disorders involving the muscles, joints, nerves and vascular compartments of the body, where certain jobs or work related factors have been shown to be associated with an increased risk of developing these disorders (2). $WMSD_s$ affects the well being of the worker resulting in poor-quality work, lower work performance and decreased motivation(3). In contrast to "occupational" diseases, where there is a direct cause-and- effect relationship between hazard and disease(e.g. asbestos and asbestosis, lead and lead poisoning), "work related" diseases are multifactorial, where the work environment and the performance of work contribute significantly to the musculoskeletal disorders (MSD_s) (4). $WMSD_s$ are disorders as inflammatory and degenerative diseases and disorders that result in pain and functional impairment, and may affect the neck, shoulders, elbows, forearms, wrists and hands (5). Apart from their impact on health, the symptoms of MSD_s may affect the productivity of these sufferers (6). This issue has been addressed mostly by considering the sickness-absence records as outcomes (6). However the effects of the symptoms when the workers are present at work has received little attention (7-9). $WMSD_S$ arises when exposed to work activities and work conditions that significantly contribute to their development or exacerbation, but not acting as the sole determinant of causation (10). It must be stressed that disorders of the neck and upper limbs is common problem in the general popu-

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lation as well as among industrial workers (11). As suggested earlier, $WMSD_S$ has been a major problem for many countries (10). However, it has only been in the last 15 or 20 yr that upper extremity musculoskeletal disorders ($UEMSD_S$), and carpal tunnel syndrome (CTS) in particular, have gained wide recognition as major medical problems among industrial and office workers in the industrialized countries (11). In the mid-1980_s the National Institute for Occupational Safety and Health (NIOSH) identified $WMSD_S$ as among the ten most important occupational safety and health concerns in many countries (11). On the follow up of the study done by Ergonomics of Postures & Movements (EPM) Research Unit(12), it was tried to assay and find the association and relation between the concise exposure index (OCRA) and the Concise Damage Index (CDI) so that they could be used for predicting foreseeable and subsequent effects of $WMSD_S$ and of occupational risk factors on the workers at risk (12).

Therefore, the final goal of the research was to make a preliminary validation of the degree of association found between the concise exposure index (OCRA) and number of the $WMSD_S$ detected as the CDI (12).

Materials and Methods

The research was carried out in Qaemshahre (Northern Iran) weaving factory located in Mazandaran Province, the north of Iran. A total of 404 male exposed workers were examined, and the study also took into account the data pertaining to a matched reference group comprising 120 male workers not exposed to any specific occupational risk factor. Regarding the quantification of exposure to increased risk, use was made of an OCRA index, proposed by Occhipinti, and of a CDI, proposed by Grieco, as an effect indicator represented by the prevalence of all the $WMSD_S$ of the upper limbs, calculated on the number of upper limbs at risk (12,13). Each of the twelve different jobs were analyzed using the method proposed by E. Occhipinti (13) and developed and completed by D. Colombini (14) in 1998 with the name of Concise exposure index (OCRA) for accurately assessing and quantifying the principal risk factors (i.e. high frequency, awkward posture, use of force, lock of recovery time, additional factors) and multiplying the corresponding multiplier factor of the mentioned principal risk factors together for calculating the OCRA exposure index (13-15). All workers in the studies were previously given a clinical examination, which provided all the clinical data relating to the individual $WMSD_S$ of the upper limbs (13, 14). The data on the various upper limb disorders classified as $WMSD_S$ were aggregated for each group of workers examined , by adding all the disorders detected in each workers for each limb(12). Consequently, a CDI was achieved in which the total number of disorders found in the group of workers is the numerator, and the total number of upper limbs at' risk' in the same group is the denominator (12,15). In other words, the number of exposed workers doubles if the risk is detected in both upper limbs (12,15). Therefore,

$$CDI = \frac{\text{Total number of } WMSD_S}{\text{Total number of limbs at increased risk}}$$

Once the relevant exposure indices(OCRA) and CDI were obtained for each group of workers , the degree of association between these variables was analyzed by studying simple and multiple regression functions, correlation coefficients as well as tests to evaluate the possible statistical significance of the associations(12, 15, 16).Also any relationship existing between the exposure index(OCRA)and the individual work-related upper limb disorders (tendinopathy, neurovascular entrapment syndrome)was examined (12, 15, 16). An assessment was also made of the degree of association using the simple (R) and squared (R^2) regression coefficients, and the F-test, which measures the statistical significance of the differences between variance based on regression and residual variance (12, 15, 16).

Occupational Repetitive Actions (OCRA) method The OCRA method is the model for the assessment of exposure to occupational repetitive movements of the upper limbs ($UEMSD_S$) (13, 15). The model is conceptually based on the procedure recommended by the NIOSH for calculating the lifting Index in manual load handling activities(13, 15). The OCRA is based on the relationship between the daily number of actions actually performed by the upper limbs in repetitive tasks (A_e), and the corresponding number of recommended actions (A_r) (13,15).

Results

Table1 summarizes the main data concerning the personal details of the group included in the analysis, and the assessment of their exposure to tasks with repetitive upper limb movements, in the different work contexts. In each context, there was taken into account the results for groups of workers carrying out identical or similar tasks. Also the summary of data from workers in a reference group of workers who had never been exposed to tasks involving repetitive movements of the upper limbs has been shown in the corresponding table. The exposure index for the reference group was fixed at a value of 0.53. As it is observed a total of 404 male workers performing various jobs were studied as case group, and the reference group comprised 120 male workers. The table also presents the results of the analysis and assessment of the various risk factors (i.e. high frequency of actions, awkward posture, use of force, lack of recovery period, additional elements), and the OCRA as an exposure assessment. The table also indicates the size of each group of workers performing the tasks, with their mean age and the length of time they had spent in the current task. The notations M and B refer, respectively, to mono-lateral and bilateral values of the exposure index in each job category.

Table2 shows the distribution of the various upper limb disorders that may be classified as $WMSD_S$ in the different work settings examined, versus the reference group. The data concerning the various disorders were totaled to obtain the overall concise lesion indicator (CDI). Table 2 also indicates the CDI values for each job category examined, presented as an indicator for the entire group of exposed workers.

Table3 shows the principal results that were obtained. The table studies the relationship between OCRA and effect indicators (CDI). The first line of analysis involved measuring the relationship between an exposure index and the various effects observed, the effects were represented by the total categories of $WMSD_S$, or by the percentage of $WMSD_S$ calculated respectively on the number of exposed subjects, or the number of exposed upper limbs (CDI). Table 3 also indicates comparison between two variables (x and y), the simple regression line equation expressing the association between in dependent (x) and dependent (y) variables, the regression coefficients and the relative F-test significance.

Table4 indicates the data relating to a variety of predicting models based on several independent variables. The dependent and independent variables considered are supplied for each, as well as the multiple regression equation, simple and squared regression coefficients, and relative significance based on the F-test.

Table 1: Personal data of male workers performing jobs examined by the study and assessment of risk factors for $WMSD_S$

Job category (Minutes of repetitive movements)	Time in Job (yr)	Frequency (no. actions$_{/min}$)	Use of force (Borg scale)	Postura risk (max.16)	Lack of recovery time (max.6)	Additional risk factors (max.12)	Exposure index	M	B
Cotton feeding & mixing unit (465´)	18.9	66	0.5	13	1	8	28	*	
Spinning wheel unit (440´)	11.7	85	1	7	4	4	33		*
String twofolding & manifolding unit (420´)	9.3	90	4	14	0	-	18		*
String double webbing unit (435´)	15.1	90	3	11	2	12	26		*
Dyeing bobbin unit (390´)	21.6	45-80 Multiple tasks	5-8	10-13	6	8	39		*
Dryer unit (410´)	17.3	55	2	12	1	4	45		*
Wrapping longcloth & starching unit (440´)	16.4	55-58 Multiple tasks	4-7	7-10	3	-	38		*
Weaving designing unit (475´)	21.2	70	7	10	4	8	53		*
Knitting unit (470´)	16.9	90	8	16	6	12	69		*
Cutting textile & counting Folds (430´)	9.7	55	4	14	3	8	41		*
Control & inspection oftextile (395´)	13.2	60	3	10	2	-	33	*	
Packing & carrying piece goods (420´)	18.8	85	8	16	6	12	73		*
Reference group (390´)	16.7	35	0.5	1	0	-	0.53		*

M: monolateral ; B: bilateral

Table 2: Distribution of the various disorders among male workers performing jobs under study versus reference group

Job category	Scapulo-humeral Peri-arthritis		Medial and lateral epicondylitis		Wrist-hand tendinitis; tendinous cysts		Carpal tunnel synd.+other entrapment neuropathies		De quervain's syndrome		Guyon canal syndrome		Total CDI by job	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cotton feeding & mixing unit	5	13.9	13	36.1	0	0	17	47.2	29	80.6	31	861	95	263.9
Spinning wheel unit	8	18.2	16	36.4	9	20.5	20	45.5	0	0	11	25	64	145.5
String twofolding & manifolding unit	21	42	10	20	0	0	19	38	0	0	13	26	63	126
String double webbing unit	15	19.2	17	21.8	6	7.7	21	26.9	3	3.8	0	0	62	79.5

Table 2: Continued….

Dyeing bobbin unit	19	29.7	5	7.8	16	25	13	20.3	1	1.6	8	12.5	62	96.9
Dryer unit	0	0	8	29.6	12	44.4	6	22.2	9	33.3	2	7.4	37	137
Wrapping longcloth & straching unit	14	25	3	5.4	25	44.6	19	33.9	0	0	4	7.1	65	116.1
Weaving designing unit	17	36.9	0	0	13	28.3	15	32.6	22	47.8	0	0	67	145.7
Knitting unit	39	21.2	22	11.9	27	14.7	57	30.9	19	10.3	5	2.7	169	91.8
Cutting textile & counting Folds	12	15.8	6	7.9	8	10.5	20	26.3	0	0	7	9.2	53	69.7
Control & inspection of textile	3	23.1	0	0	5	38.5	9	69.2	0	0	0	0	17	130.8
Packing & carrying piece goods	19	32.8	2	3.4	0	0	13	22.4	8	13.8	10	17.2	52	89.7
Reference group	1	0.4	0	0	3	1.25	0	0	0	0	3	1.25	7	2.9

M: monolateral ; B: bilateral

Table 3: Relationship between variables and injury variables: simple regression lines, simple (R) and squared correlation coefficients (R^2) and level of significance of the association (*P*; F-test).

Job category	**Comparison Between variables**		**Regression line equation**	**Simple correlation coefficient (R)**	**Squared correlation coefficient (R^2)**	***P***
	x	**y**				
Cotton feeding & mixing unit	Log OCRA	Log CDI×100	y= 0.872+0.243x	0.68	0.39	0.020
Spinning wheel unit	Log OCRA	Log CDI×100	y= 0.932+0.691x	0.98	0.65	0.004
String twofolding & manifolding unit	Log OCRA	Log CDI×100	y = 0.816+0.532x	0.45	0.33	0.0026
String double webbing unit	Log OCRA	Log CDI×100	y= 0.863+0.142x	0.83	0.62	0.0015
Dyeing bobbin unit	Log OCRA	Log CDI×100	y= 0.964+0.299x	0.75	0.59	0.008
Dryer unit	Log OCRA	Log CDI×100	y= 0.858+0.161x	0.69	0.47	0.004
Wrapping longcloth & straching unit	Log OCRA	Log CDI×100	y= 0.759+0.206x	0.87	0.68	0.016
Weaving designing unit	Log OCRA	Log CDI×100	y= 0.983+0.295x	0.90	0.77	0.013
Knitting unit	Log OCRA	Log CDI×100	y= 1.252+0.973x	0.97	0.85	0.001
Cutting textile & counting folds	Log OCRA	Log CDI×100	y= 0.692+0.113x	0.85	0.69	0.013
Control & inspection of textile	Log OCRA	Log CDI×100	y=1.003+0.793x	0.79	0.61	0.0013
Packing & carrying piece goods	Log OCRA	Log CDI×100	y= 1.061+0.871x	0.64	0.49	0.011

Table 4: Significant models of multiple linear regressions between a concise $WMSD_S$ variable (dependent): variables examined ,equations, regression coefficients ,significance at F-test.

Dependent variable(y)	Independent variables(x)	Equation	R	R^2	*P*
Log CDI_{total}	Log OCRA index without recovery Periods(x_1)	$y = -0.995+0.725x_1+0.693x_2$	0.97	0.83	0.003
	Log No. hours without recovery Periods(x_2)				
Log CDI_{total}	Log OCRA index(x_1)	$y = -1.089+0.818x_1+0.795x_2$	0.89	0.77	0.008
	Log No. hours without recovery Periods(x_2)				
Log CDI_{total}	Log OCRA index(x_1)	$y = -1.281+0.927x_1+0.844x_2+0.214x_3$	0.93	0.85	0.012
	Log length of time in job(x_2)				
	Log No. hours without recovery Periods(x_3)				

Discussion

The actions analyzed all featured a high frequency, on average >73 actions/min, in some cases reaching levels of even 90 actions/min, varied considerably from job to job, with the highest peaks among workers carrying out string twofolding and manifolding unit operations, string double webbing unit actions, and knitting unit actions. Elbow, wrist, and hand postures were extreme in there situations, and very bad in all the others. There was a great variability in the distribution of recovery periods among the twelve work settings analyzed. The highest force exertions were related to knitting unit, packing & carrying piece goods, and dyeing bobbin unit, and the lowest force exertion was allocated to the cotton feeding and mixing unit. Equally variable was the workers' exposure to additional elements such as high-precision work; vibrations; use of glove; and exposure to low or high temperature; and etc. The exposure index values calculated using the OCRA procedure, were invariably high, and ranged from a minimum of 18 for the string twofolding and manifolding unit, to a maximum of 73 and 69 for the packing and carrying piece goods and knitting unit respectively whiles the reference group was allocated a concise index value of 0.53.

As regards Scapulo-humeral periathritis (reported 0.4% of the male workers of reference group), the prevalence of the disorder was quite high among the string twofolding and manifolding unit (42%), weaving designing unit (36.9%), packing and carrying piece goods (32.8%), dyeing bobbin unit (29.7%), and so forth. For other disorders, this procedure has also been repeated (Table2). As mentioned previously, the concise damage (lesion or injury) indices (CDI) by job were obtained by dividing the number of disorders by the number of upper limbs at risk in the exposed workers (4, 7). As it was observed the highest prevalence of medial and lateral epicondylitis (0% in the reference group) was gained in spinning wheel unit (36.4%), and cotton feeding & mixing unit (36.1%).

Tendinitis of the hand-wrist, including tendinous cysts (1.25% in the reference group) appeared to be completely high in the workers employed in the wrapping designing unit (44.6%), and dryer unit (44.4%), etc. Carpal tunnel syndrome, including various other entrapment neuropathies (0% in the reference group) seemed to be the most widespread disorder with all jobs reporting frequencies in excess of 20%. De Quervain's syndrome (reported 0% in the reference group) appeared to be quite low excepting four units including cotton feeding and mixing unit (80.6%), weaving designing unit (47.8%), dryer unit (33.3%), and knitting unit (10.3%). Guyon canal syndrome (1.25% in the reference group) seemed to be rather low excepting several jobs including cotton feeding and mixing unit (86.1%), string twofolding and manifolding (26%), spinning wheel unit (25%), packing and carrying piece goods (17.2%), and dyeing bobbin unit (12.5%).The values range from 69.7% to a remarkably high 263.9%, a figure that means that almost every member of the group on average suffered from more than one $WMSD_S$ for each limb exposed to specific risk. It should be noted that the highest prevalence of $WMSD_S$ detected among the cotton feeding and mixing unit workers (263.9%), weaving designing unit workers (145.7%), spinning wheel unit (145.5%), dryer unit (137%), control and inspection of textile (130.8%), and so forth. There was a very wide gap in the prevalence of $WMSD_S$ detected among the cotton feeding and mixing unit (263.9%), the weaving designing unit (145.7%), and the cutting textile and counting folds (69.7%) whiles in the reference group, the CDI value was 2.9%.

Since the best associations for the total disorders were invariably those between percentage disorders and the number of upper limbs at risk, table 3 only includes the data for the respective relationship (12,16). Based on the data shown in Table 3, it can thus be demonstrated that the most significant relationships are obtained when the exposure variable is linked to a variable taking into account the total $WMSD_S$ (like CDI) (12, 16). It should be stressed that the effectiveness of the indicator when all the percentage $WMSD_S$ detected in group of exposed workers are taken into account with respect to the common denominator represented by the number of upper limbs deemed to be 'at risk' (12,16). The best result was obtained by making transformation of the two variables (x and y) as a logarithmic conversion of the relative exposure (OCRA) and injury indices under examination (12,16).

The multiple regression models show how the concise damage index (CDI) can be expressed in terms of different variables (include: OCRA index, lack of recovery period, length of time in job, etc.) (Table 4) (12,16). Among the models shown in table 4, special attention should be devoted to the one that treats as separate variables both the OCRA index recalculated without taking recovery times into account, and the descriptive classification of the adequacy of the recovery times (12). The predictive performance of this model is extremely interesting ($R= 0.97$, $R^2= 0.83$, $P= 0.002$) and indicates on the one hand how important 'recovery times' are as a risk factor (as defined by Colombini, 1998) and on the other that their specific weight in the overall architecture of the OCRA index needs to be seriously reconsidered (12-15).

Finally, the research has been performed on the application of methods based on an analysis of the 'exposure' and 'injuries' associated with jobs featuring repetitive movements of the upper limbs (12, 15). Regarding the aforesaid effects, the OCRA exposure index features a satisfactory level of association, and therefore, after suitable modification, proves to be a valid predictor of increased risks (12,15). Based on the results obtained in the research, it clearly appears that the linear regression line between the logarithm of the OCRA index and the logarithm of the concise 'damage' index (CDI) constitutes a valid predictive model (12, 16). Significant associations were reported between exposure indicators (OCRA) and effect indicators (CDI) (12, 16). When a logarithmic conversion of the relative exposure (OCRA) and injury indices was carried out, a simple linear regression model resulted that seems to provide a satisfactory predictive performance of the risk of $WMSD_S$ of the upper limbs, based on exposure index (12, 16). The research also certificated the efficiency of various other models presented to predict effects based on multiple linear regression functions (12, 16). Also the models designed to predict an increased risk of upper limb $WMSD_S$ should include not only a concise index of exposure to biomechanical overload, but also parameters relative to number, age, lack of recovery period, etc. of exposed subjects (12, 15). Finally, it must be considered that the OCRA exposure indices of >4 need to be as predictive of a significant high occurrence of specific lesions in the relative group of exposed workers, therefore these workers must be placed in the so-called red area (12-15). OCRA index values ranging from 0.75 to 4 should be considered as inter mediate (the so-called amber area), in which the relative values of the index neither point necessarily to an excess of 'lesions', nor rule them out entirely in the specific group of exposed workers (12-15).

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