PREVENTION & RESEARCH
Freely available online
ISSN:2240-2594

THE EVALUATION OF THE UPPER EXTREMITY BIOMECHANICAL OVERLOAD

VALUTAZIONE DEL SOVRACCARICO BIOMECCANICO DELL' ARTO SUPERIORE

Ciarrocca M [1], Caciari T [1], Capozzella A [1], Nardone N [1], Rosati MV [1], De Sio S [1], Di Pastena C [1], Schifano MP [1], Andreozzi G [1], Scala B [1], Monti C [1], Corbosiero P [1], Scimitto L [1], Sinibaldi F [1], Miracco P [1], Fiaschetti M [1], Cetica C [1], Tomei G [2], Tomei F [1], Sancini A [1]

[1] Department of Anatomy, Histology, Medical-Legal and Orthopaedics, Unit of Occupational Medicine (Dir: Prof. F. Tomei), "Sapienza" University of Rome, Italy
[2] Department of Neurology and Psychiatry, "Sapienza" University of Rome, Italy

[1] Dipartimento di Anatomia, Istologia, Medicina Legale e Ortopedia, Unità di Medicina del Lavoro (Dir: Prof. F. Tomei), "Sapienza" Università di Roma
[2] Dipartimento di Neurologia e Psichiatria, "Sapienza" Università di Roma

Citation: Ciarrocca M, Caciari T, Capozzella A, et al. The evaluation of the upper extremity biomechanical overload. Prevent Res 2012; 2 (1): 19-26

Key words: repetitive activity, WMSDs, assessment of the work-related risk

Parole chiave: movimenti ripetitivi, WMSDs, valutazione del rischio lavoro-correlato

Abstract

Objectives: The pathologies due to repetitive activity of the upper limbs, well-known as WMSDs (Work Related Musculoskeletal Disorders), have considerably increased in the last years. At the moment there are no validated methods for the assessment of the work-related risk.

Methods: This study wants to compare two different methods proposed in literature for the assessment of the work-related risk, combining objective and subjective measures.
The assembling of airbag modules supported by pneumatic or power supplied machines implies different steps and takes place along two production lines (line A and line B).

Results: The risk evaluation with the S.I. (Strain Index) method gave comparable results.
The risk evaluation carried out through TLV–ACGIH (HAL method) has shown a professional exposure higher than TLV for line A; on the contrary, with regard to line B, the final values of risk index correspond to AL value.

Conclusions: HAL is a better method to evaluate Work Related Musculoskeletal Disorders in real working conditions, characterized by force peaks and repetitive movements like the ones workers of an industry are exposed to. The introduction of organizational and mechanical measures could considerably reduce the relative risk index.

Abstract

Obiettivi : Le patologie correlate con i movimenti ripetitivi degli arti superiori, note nella letteratura scientifica come WMSDs (Work Related Musculoskeletal Disorders), sono notevolmente incrementate negli ultimi anni. Al momento non esistono metodi validati per la valutazione del rischio correlato al lavoro.

Metodi*:* Questo studio mette a confronto due diversi metodi per la valutazione del rischio proposti in letteratura, abbinando misure soggettive ed oggettive. Sono state analizzate due linee di produzione (linea A e linea B) coinvolgenti diverse fasi lungo le quali avviene l'assemblaggio di moduli airbag, supportato da macchine pneumatiche o ad alimentazione elettrica.

Risultati: La valutazione del rischio effettuata con il metodo S.I. (Strain Index) fornisce risultati comparabili tra loro.
La valutazione dei rischi effettuata attraverso TLV–ACGIH (metodo HAL) ha dimostrato, per la linea A, una esposizione professionale dei lavoratori superiore al TLV; al contrario, per quanto riguarda la linea B, i valori finali di indice di rischio corrispondono al valore di AL.

Conclusioni: HAL rappresenta il metodo migliore per valutare i disturbi lavoro correlati in condizioni di lavoro reali, caratterizzati dall'esposizione a picchi di forza e movimenti ripetitivi.
L'introduzione di misure organizzative e meccaniche potrebbe ridurre considerevolmente l'indice di rischio relativo.

Introduction

Repeated movements of upper limbs typical some working activities may lead to musculoskeletal disorders, known in literature as WMSDs (1). The onset of these disorders, which have an acknowledged multifactorial aetiology, is associated with different working risk factors, that have therefore to be assessed, but may also depend on non-professional factors (2, 3).

The incidence of these disorders has considerably increased during the last decade (4).

In Italy, the most recent data from INAIL show an increase in reported WMSDs from 139 in 1996 to 1500 in 2000, and a number of admitted cases ranging from 10 to 990 (5).

The evaluation of risk is the issue of major concern; it has recently acquired a central role in the practice of occupational physicians, mainly in relation to risks such as WMSDs, often neglected because of their absent or incomplete recognition (6, 7). The use of risk evaluation methods could be the basis for structural-organizational interventions (modification of work position, of tooling, of time work) or preventive interventions (information and training courses, health surveillance and monitoring of critical parameters) (8, 9).

Several patterns of study, though not quite validated, have shown a series of occupational factors, such as the high frequency of movements, the strength used when working, the inadequate postures assumed at work, the insufficient recovery time, vibration and others, which must be taken into consideration studying the origin of the pathologies affecting the upper limbs (10). The methods most frequently adopted for the evaluation of musculoskeletal disorders are OSHA checklist, Strain Index (11), OCRA index (12, 13) and TLV-ACGIH (14).

The evaluation provided by these methods does not take into account mental exertion which together with physical exertion can cause an increase of accidents and a decrease of production (15, 16).

The methods selected for this study are the Strain Index and the TLV-ACGIH (HAL method) (17, 18), being the most suitable for the studied activity, which is characterized by high repetitiveness and considerable use of strength.

The Strain Index is a semi-quantitative evaluation method for the assessment of different parameters: intensity and duration of the effort, number of efforts/min., hand and wrist postures, labourer's working rate and daily duration of the working activity (11).

The TLV published by ACGIH, related to the hand-wrist-forearm zone, is a quantitative method that can be applied to manual activities involving the performance of repetitive and similar actions or movements for at least 4 hours/day (19).

The combination between mean hand activity level HAL and normalized force peak, assessed on scales from 0 to 10, allows to compare this evaluation with the TLV (the level beyond which the prevalence of musculoskeletal disorders becomes manifest).

The aim of this study is to evaluate the risk of exposure in a group of individuals working in a firm which produces components for car industry, using the ACGIH TLV (HAL method) and Moore and Garg's Strain Index and comparing the two methods.

Methods

A research was carried out on two production lines (line A and line B) in a factory for the semiautomatic assembling of plastic and metal components.

Specific socio-communicative competences were used for the development of tools suitable to the collection of information and to the analysis and organization of data.

On the basis of information provided, the following surveys were performed:

• analysis of working tasks, characteristics of the effort required to the upper limbs and of the positions assumed at work , assessment of: equipment and materials employed, repetitive actions, presence of recovery and rest periods, strenght applied by the workers (Borg rating scale).

• analysis of the working processes by means of direct observation of technicians and videorecording of working operations during several manufacturing cycles, according to the products manufactured in every production line;

• subsequent examination of videorecordings with count of the single movements and evaluation of the mean frequency of the hand movements;

• selection of complementary data, such as information on working organization, workload for each working task, number of units processed within fixed time, necessary for the application of ergonomic evaluation models.

On the basis of these data and those collected during the inspections and videorecordings the upper limbs exposure to biomechanical overload was evaluated with regard to all the tasks/positions at work.

Biomechanical evaluations were performed through the calculation of specific risk index, using the ACGIH TLV (HAL method) and the Strain Index.

As to the ACGIH TLV (HAL method), the hand activity level HAL was measured by assessing the mean frequency of hand movements and the duration of the "Duty cycle" (percentage of working cycle where the force is over 5% of the maximum), i.e. by assessing the distribution of work and rest/recovery periods (19) (Table 1).

Table 1. *HAL calculation scale relative to strain frequency and to "Duty Cycle"*

Frequency (effort/sec)	**Period (sec/effort)**	**Duty Cycle (%)**				
		0-20	20-40	40-60	60-80	80-100
0.125	8.0	1	1	-	-	-
0.25	4.0	2	2	3	-	-
0.5	2.0	3	4	5	5	6
1.0	1.0	4	5	5	6	7
2.0	0.5	-	5	6	7	8

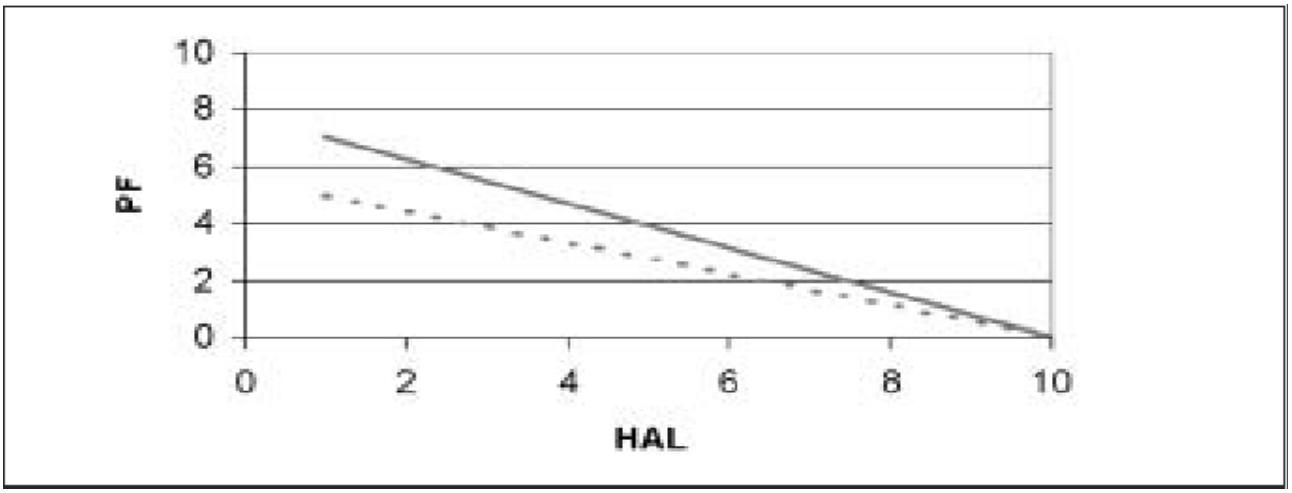
The peak of manual force was evaluated by our expert evaluators.

The peak force was "normalized" (the ratio between the strength required to carry out the job and the ability to exert a force by general population employed in the same job) on a scale ranging from 0 to 10, which correspond respectively to 0% and 100% of the reference force applicable to normal population.

The peak force was obtained from the observation of several workers appropriately trained.20 The combination on Cartesian axes of the resulting values provides the exposure level of the analysed position.

This level must then be compared to the TLV, the threshold limit value representing the threshold beyond which the prevalence of musculoskeletal disorders significantly increases (Figure 1).

Figure 1. *TLV based on hand activity level (HAL) and peak force (Pf) to reduce musculoskeletal disorders.*



———— *Grey continuos line: TLV*
-------- *Grey outlined line: AL*

For the application of Moore and Garg's method, the intensity and duration of the effort were assessed, together with hand and wrist postural aspects. Work paces and daily task duration were also considered. The resulting scores correspond to the relative coefficients to be multiplied for the computation of SI (11).
Two production lines were analysed (line A and line B), along which the assembling of airbag modules takes place involving different steps, supported by pneumatic or power supply machines. As to line A, the risk was evaluated on the basis of 480-minute shifts with 80 minutes of rest. As to line B, the evaluation was based on 480-minute shifts with 60 minutes of rest.
The operations performed on line A include: preparation of components, assembling of subunits, bending, welding, packaging. The whole operation is defined "cycle".
The operations performed on line B are the following: preparation, bending, pressing, riveting, packaging.

Results

The risk evaluation on line A carried out through ACGIH TLV has shown, a professional exposure of workers higher than TLV in the positions of retainer assembling preparation, subunit assembling and bending machine. These positions are characterized by particularly high HAL values from 6.9 to 7 and P.f. values from 3 to 5.5, while the index risk value was lower than the limit of action AL in the welding-packaging position. These tasks are those characterised by a higher number of repetitive movements and which require a greater effort to the operator.
As to line B, the final values of risk index correspond to AL value. Along this assembling line, in fact, tasks don't require use of force or particularly high HAL levels. The values obtained for the preparation and pressing positions correspond to TLV, those in the bending position are below AL, while those concerning the riveting and packaging positions are between TLV and AL.
The Strain Index values obtained in line A were within the range of those considered "probably at risk", while the global result for line B is within range 2 (uncertain risk). Very high values of SI were also reported for bending and assembling tasks.
Assuming the introduction in line A of changes, such as automation and/or the auxiliation of some steps in the cycle, in order to reduce Pf, the reduction of repetitiveness and operators turnover in the different positions, a reduced biomechanical risk can be observed (values below AL).

Discussion

The analysis of line A shows that the highest risk is related to bending and assembling tasks (subunits, retainer assembling preparation), which have the highest SI and HAL values (highest value 7) and high Pf values (highest value 5.5). This makes comparable the final values of risk index (beyond TLV) and SI (probable risk). On the contrary, in line B the final value corresponds to AL and to a range 2 SI (uncertain risk), and this is due to the lack of subunit assembling and assembling preparation positions, which are the ones at higher risk. Also in this case, the two values obtained are comparable.

To reduce the final value of line A risk index, some hypotheses of ergonomic intervention were formulated: reduction in the exposure to levels below AL can be achieved by reducing Pf, through automation and/or auxiliation of the most critical steps of the cycle, or through operators turnover in the different positions and a reduced repetitiveness by means of suitable instruments. Hence, the applied manual force becomes one of the most important factor to be considered about the relative risk index, since turnover alone is not enough to significantly reduce risk index values.

Conclusions

The risk evaluation carried out denotes that in line A different operations expose workers to biomechanical overload, requiring a considerable use of force and high levels of repetitiveness.

In particular, the presence of high force peaks increases considerably the final level of risk index, causing, as we have observed, the overcoming of TLV in certain lines. The introduction of convenient organizational and mechanical measures, such as a reduced repetitiveness through technical interventions and workers turnover in the different positions (e.g. automatic screwer, automatic or pedal press, adjustable schedule program, automatic systems of labelling, etc.), as well as a reduction in force peaks through potential automation and/or auxiliation of the most critical steps of the cycle could considerably reduce the relative risk index.

At present, the limit of all the evaluation methods is the absence of mental exertion analysis, which could interfere with mental health (15, 16).

For this reason, we are studying on stressor-exposed workers the possibility of using some parameters to evaluate mental stress and exertion and some early biomarker valuable for groups of workers (21-30). HAL method is able to better valuate the results from WMSDs in real working conditions, as those workers of an industry characterized by force peaks and repetitive movements are exposed to.

Abbrevations

WMSDs, Work-Related Musculoskeletal Disorders; INAIL, National institute for insurance against industrial injuries; OSHA, Occupational Safety and Health Administration; SI, Strain Index; OCRA index, Occupational Repetitive Actions; ACGIH, American Conference of Governmental Industrial Hygienists; HAL, Hand Activity Level; Pf , force peak; AL, limit of action.

References

1. Colombini D, Occhipinti E. Development of simple tools for risk identification and prevention of WMSDs (work related muscular-skeletal disorders): application experience in small and craft industries. Med Lav 2011; 102 (1): 3-5.
2. Apostoli P. Musculoskeletal disorders caused by repetitive trauma of the upper limbs: a paradigm of the development of occupational diseases and industrial medicine. G Ital Med Lav Ergon 2001; 23: 87-98.
3. Occhipinti E, Colombini D. From complexity to simplification: contribution of the EPM Research Unit to producing a toolkit for risk assessment and management of biomechanical overload and WMSDs prevention]. Med Lav 2011; 102 (2): 174-192.
4. Nicoletti S, Battevi N. Upper-limb work-related musculoskeletal disorders (UL-WMSDs) and latency of effect. Med Lav 2008; 99 (5): 352-361.
5. Balletta A, Clemente M, Milesi AF. Le patologie da traumi ripetuti. Andamento delle denunce e dei riconoscimenti in ambito INAIL. G Ital Med Lav 2001; 2: 151-155.
6. Apostoli P, Sala E, Gullino A, et al. Analisi comparata dell'applicazione di quattro metodi per la valutazione del rischio biomeccanico per l'arto superiore. G Ital Med Lav Ergon 2004; 26 (3): 223-241.
7. Martinelli R, Casilli A, Fanelli C, et al. Risk assessment in upper limb overload G Ital Med Lav Ergon 2007; 29 (Suppl.3): 595-596.
8. Occhipinti E. Working tasks with upper limbs repetitive movements: analysis of different methods for risk assessmentG Ital Med Lav Ergon 2008; 30 (Suppl.3): 32-38.
9. Capodoglio EM, Facioli M, Bazzini G. La valutazione del rischio connesso ad attività lavorative: sperimentazione di diversi metodi proposti dalla letteratura. G Ital Med Lav Ergon 2001; 23 (4): 467-476.
10. Dempsey PG. A critical review of biomechanical, epidemiological, physiological and psychophysical criteria for designing manual materials handling tasks. Ergonomics 1998; 41 (1): 73-88.
11. Moore JS, Garg A. The strain index: a proposed method to analyse jobs for risk of distal upper extremity disorders. Am Ind Hyg Ass 1995; 56: 443-458.
12. Occhipinti E. OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. Ergonomics 1998; 41 (9): 1290-1331
13. Nicoletti S, Consonni D, Carino M, et al. Upper limb work-related musculoskeletal disorders (UL-WMSDs): a retrospective cohort study in three large factories of the upholstered furniture industry Med Lav 2008; 99 (4): 281-296.
14. American Conference of Governmental Industrial Hygienistis (ACGIH). TLV and BEI 2001. Ergonomics, statement on work-related musculoskeletal disorders, hand activity level; ACGIH® Worldwide: Cincinnati, Ohio, 2001.
15. Andersen JH, Kaergaard A, Frost P. Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. Spine 2002; 27: 660-667.
16. Bonde JP, Mikkelsen S, Andersen JH, et al. Understanding work related musculoskeletal pain: does repetitive work cause stress symptoms? Occup Environ Med 2005; 62: 41-48.
17. Spielholz P, Bao S, Howard N, et al. Reliability and validity assessment of the hand activity level threshold limit value and strain index using expert ratings of mono-task jobsJ Occup Environ Hyg 2008; 5 (4): 250-257.
18. Tomei G, Draicchio F, Nicassio P, et al. Use of TLV-ACGIH (HAL) and Strain Index for the evaluation of the upper extremity biomechanical overloadG Ital Med Lav Ergon 2005; 27 (3): 351-354.
19. Violante FS, Isolani L, Raffi GB. Case definition for upper limb disorders. In: Occupational Ergonomics. Work related musculoskeletal disorders of upper limb and back. Armstrong T, Kilbom A (Eds); Taylor and Francis: London and New York 2000; 120-128.
20. Borg G. Borg's Perceived exertion and pain scales. Human Kinetics, Champain (USA), 1998.
21. Pancheri P, Martini A, Tarsitani L, et al. Assessment of subjective stress in the Municipal Police Force of the city of Rome. Stress and Health 2002; 18: 127-132.

22. Tomei F, Rosati MV, Ciarrocca M, et al. Plasma cortisol levels and workers exposed to urban pollutants. Industrial Heath 2003; 41 (4): 320-326.
23. Tomei F, Rosati MV, Ciarrocca M, et al. Work exposure to urban pollutants and urinary homovanillic acid. J Environ Sci Health (Part A) 2003; 38 (12): 2909-2918.
24. Tomei F, Rosati MV, Baccolo TP, et al. Plasma concentration of adrenocorticotropic hormone in traffic policemen. J Occup Health 2003; 45: 242-247.
25. Tomei F, Rosati MV, Baccolo TP, et al. Response of lympho-monocytes to phytohemagglutinin in urban workers. Environ Toxicol Phar 2004; 17 (1): 13-18.
26. Tomei F, Rosati MV, Baccolo TP, et al. Exposure to urban pollutants and serum levels of IgG anti Herpes Simplex Virus Type 1. Industrial Health 2004; 42 (4): 408-414.
27. Monti C, Ciarrocca M, Cardella C, et al. Exposure to urban stressor and effects on luteinizing hormone (LH) in female outdoor workers.J Environ Sci Health A Tox Hazard Subst Environ Eng 2006; 41(8): 1437-1448.
28. Tomei G, Capozzella A, Ciarrocca M, et al. Plasma dopamine in workers exposed to urban stressor. Toxicol Ind Health 2007; 23 (7): 421-427.
29. Tomao E, Tomei G, Rosati MV, et al. Luteinizing hormone (LH) levels in male workers exposed to urban stressors. Sci Total Environ 2009; 407 (16): 4591-4595.
30. Tomei G, Tomao E, Ciarrocca M, et al. Follicle-stimulating hormone levels in male workers exposed to urban chemical, physical, and psychosocial stressors.Toxicol Ind Health 2009; 25 (6): 395-402.

Corresponding Author: Gianfranco Tomei
Department of Neurology and Psychiatry, "Sapienza" University of Rome, Italy
e-mail: info@preventionandresearch.com

Autore di riferimento: Gianfranco Tomei
Dipartimento di Neurologia e Psichiatria, “Sapienza” Università di Roma
e-mail: info@preventionandresearch.com