Relevant Risk Factors Linked to Musculoskeletal Discomfort in Workers of Meat Processing Industry

Mervyn Márquez and Miguel Márquez
Industrial Engineering Department
National Experimental University of Táchira
San Cristóbal, Venezuela
mervyn@unet.edu.ve, mmarquez@unet.edu.ve

Abstract

Work-related Musculoskeletal Disorders (WMSDs) represent one of the most common occupational diseases that affect large numbers of industrial workers. The aim of the study is to identify relevant risk factors associated with the existence of musculoskeletal discomfort or pain, according to the affected body part. A transverse field study was conducted, on a sample of 174 workers of three Venezuelan meat-processing industries. The standardized Nordic questionnaire was used for the identification of WMSDs and the data mining methods *CfsSubsetEval* and *ConsistencySubsetEval* were used for the selection of the relevant factors, which are available in *Weka*. A WMSDs prevalence of 77% was found; excels the shoulders (49.4%) and back (47.1%) as the body parts that affect most workers. The factors that presented the greatest correspondence with the discomforts of the shoulders are postural overload, repeatability, psychosocial demands and time working in the same task. In the case of the discomforts of back, the factors selected are postural overload, lifting of loads, pushing or pulling loads, low social support and the medical history. The multifactorial etiology of WMSDs was confirmed.

Keywords
Occupational health, risk factors, data mining, workers, work-related musculoskeletal disorders.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) include a large number of painful inflammatory and degenerative conditions that affect muscles, tendons, ligaments, joints, nerves, and blood vessels. These include clinical syndromes (tenosynovitis, epicondylitis, bursitis), nerve compression disorders (carpal tunnel, sciatica) and osteoarthrosis, but also other less standardized conditions such as myalgias, back pain, and other localized pain syndromes not attributable to a known pathology (Punnett & Wegman, 2004).

In general, musculoskeletal traumatic injuries are subdivided into two large groups: those that develop gradually and are caused by the excessive use of the different components of the locomotor apparatus mentioned above, and those that occur due to acute trauma or fractures, originating by accidents (Canadian Center for Occupational Health and Safety, 2014 and Attwood, Deeb & Danz, 2004). This work is focused on the WMSDs of the first group, those caused by repeated exposure to a type of physical activity.

WMSDs represent considerable costs and impact on the quality of life, since they can generate a lot of pain and suffering in affected workers, decrease their productivity and quality in the work, and even cause disability (Almagro, Borrero, Paramio, Carmona & Sierra, 2009 and Chandna, Deswal & Pal, 2010). This type of disease has spread throughout the world and is quite prevalent in many countries, in the EU member states for example, WMSDs are the most common work-related health disorders, accounting for 59% of all occupational diseases recognized by European statistics in 2005, and accounting for more than 10% of all years of disability lost in 2009 (International Labor Organization, ILO, 2013).

Most of authors agree on a multifactorial etiology in the process of generating WMSDs, which makes it more complex to understand, limiting the effectiveness of intervention programs. In addition, not all factors that may interfere with the occurrence of WMSDs have the same level of correspondence, so depending on the type of disorder and the body part affected, some risk factors will be more important than others.

The aimed of this study is to find the most determinant risk factors for the occurrence of WMSDs, depending on the affected part of the body. First, the prevalence of musculoskeletal discomfort in each body part was determined. Thereafter, the possible risk factors (biomechanical, psychosocial and individual) related to WMSDs were evaluated, according to the bibliography consulted. Finally, the correspondences between these risk factors and the different WMSDs were established, through data mining techniques.

2. Material and methods

The study initially has a descriptive level, represented by the characterization of the musculoskeletal discomfort perceived by the workers and the main risk factors analyzed in their respective places of work. Thereafter, the study has a correlational level, represented by the relationships between risk factors and WMSDs. Descriptive research forms the basis of correlational studies (Hernández, Fernández & Baptista, 2010).
The cross-sectional study was done between July 2014 and March 2015 in three Venezuelan industries dedicated to the processing and production of meat products, such as hams, sausages, chops and the like. The sample consisted of 174 workers in the operating area of these companies.
Several techniques and instruments were used to collect the data, based on direct observation, surveys and video analysis, all under the research protocols established in the Declaration of Helsinki. In this way, the Standardized Nordic Questionnaire developed by Kuorinka et al (1987) was used to know the existence and type of musculoskeletal discomfort present in the sample. In addition, different methods were used for the evaluation of the most important risk factors. The RULA (Rapid Upper Limb Assessment) method was used to assess postural overload (McAtamney & Corlett, 1993). The OCRA (Occupational Repetitive Action) Checklist method was used for repetitive movements (Colombini, Occhipinti & Grieco, 2002). The revised NIOSH (National Institute for Occupational Safety and Health) equation for lifting loads (Universidad Politécnica de Valencia, UPV, 2006). The ERGO method for the pushing and pulling loads (Instituto de Biomecánica de Valencia, IBV, 2011). The CoPsoQ-ISTAS21 method (Instituto Sindical de Trabajo, Ambiente y Salud, ISTAS, 2010 and IBV, 2011) for psychosocial factors. The latter include the analysis of six dimensions: psychological demands, active work and development possibilities, insecurity, social support and quality of leadership, double presence and esteem.
A questionnaire was used to collect information on individual factors of workers, related to their sociodemographic, anthropometric and labor profile, among them: habits related to domestic work, physical training and smoking, height and weight, time working in the same task, activities developed, overtime and rotation.
To analyze the correlation between the different risk factors studied and the WMSDs, data mining techniques were used, through the *Weka* (Waikato Environment for Knowledge Analysis) tool, that is an environment for the knowledge analysis of the Waikato University of New Zealand (Witten & Frank, 2005). This platform offers a set of modules, including the called "attribute selection", that allows analyzing the relevance of a group of factors on a particular phenomenon, generating subsets of relevant attributes from different selection methods and different search strategies. In this case, the methods *CfsSubsetEval* and *ConsistencySubsetEval* were used. The first is based on correlations, tries to obtain the set of attributes most correlated with the class and with less correlation with each other, while the second is based on the degree of consistency in class values when the training instances are projected in the set.
After obtaining the different subsets of attributes that are derived from the combination of the selection methods with the different search strategies, classification methods were used (available in *Weka)* to select the subset of attributes that allows to maximize the proportion of successes or instances classified correctly. In this way, the subset of factors that best correlate with the WMSDs of each part of the body were obtained.

3. Results

3.1 Prevalence of musculoskeletal discomfort

After consulting the sample of workers, about their possible suffering of musculoskeletal discomfort with the Standardized Nordic Questionnaire, it was possible to know the prevalence of WMSDs. A general prevalence of musculoskeletal discomfort of 77% (134 workers) was obtained, with only 40 workers who did not feel or have felt discomfort of this type in the last year.
The human body was subdivided into six parts: neck, shoulders, back, elbows / forearms, hands / wrists, and legs / feet, with the purpose of detailing the affected part of the body. In this way, the shoulders represented the most

common region where musculoskeletal discomfort is located, with 49.4% (86 workers) of the sample (See Figure 1). In second place, the back obtained 47.1% (82 workers). Third, the hands and wrists with 31.6% (55 workers) and the neck with 29.3% (51 workers).

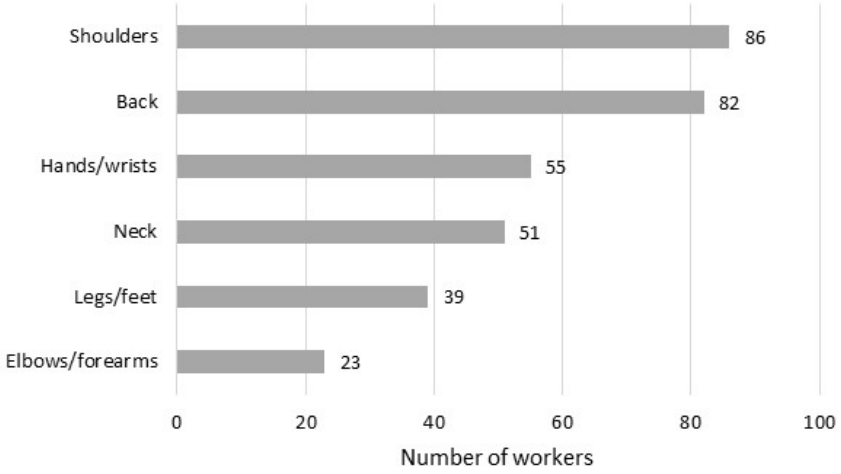

Figure 1. Prevalence of WMSDs according to part body

3.2 Evaluation of biomechanical, psychosocial and individual factors

The biomechanical factors evaluated were postural overload, repetitive movements, lifting heavy loads and pushing or pulling heavy loads. In the case of postural overload, the RULA method establishes four levels of action: the posture is acceptable (1), changes in task may be required (2), redesigning the task is required (3) or urgent changes are required (4). Thus, in general terms, the highest proportion of workers (44.8%) were exposed to a level 2, followed by 37.4% of workers exposed to a level 3.

In terms of repeatability of movements, the OCRA checklist method defines six different risk levels: optimal (1), acceptable (2), very light (3), light (4), medium (5) and high (6). In this way, the most frequent level of risk among the consulted workers is level 3, with 27.6%, followed by risk levels 2 and 4, with a 19.5% of persons, in each case.

The biomechanical risk factors related to the lifting of loads (evaluated by the revised NIOSH equation) and the pushing or pulling of loads (evaluated by the ERGO method) are categorized into three levels of risk: acceptable (1), moderate (2) and high or unacceptable (3). Thus, the highest proportion of workers was exposed to an acceptable level of risk (1) from the point of view of lifting loads, registering a total of 59.2% of the personnel surveyed, while in the case of pushing or pulling loads 84.5% are also located at the acceptable level (1). Not all workers do tasks that require manual handling of loads, hence acceptable levels predominate in the sample analyzed.

Regarding psychosocial factors, the six dimensions considered were evaluated using the CoPsoQ-ISTAS21 method, which categorizes the level of exposure in three classes: more favorable (1), intermediate (2) and more unfavorable (3). In this way, the factors of insecurity and esteem obtained the highest proportion of cases in level 3 (most unfavorable), with 85.6% and 61.5%, respectively. Figure 2 shows the distribution of workers according to the level of risk to which they are exposed, in each factor evaluated.

In terms of individual factors, the sample of workers is mostly male (81%), with a mean age of 34.9 years, and an average body mass index of 27.9 kilograms / meter2 (kg / m^2), which corresponds to the level of pre-obesity according to the World Health Organization. Additionally, it was found that 93.7% of the sample consulted did not smoke and that 27% had a medical history related to musculoskeletal disorders of different nature. Other labor data indicate that 47.1% of the respondents work overtime, 58% rotate among different tasks in their area of work, and the time working in the current position averages 5.6 years.

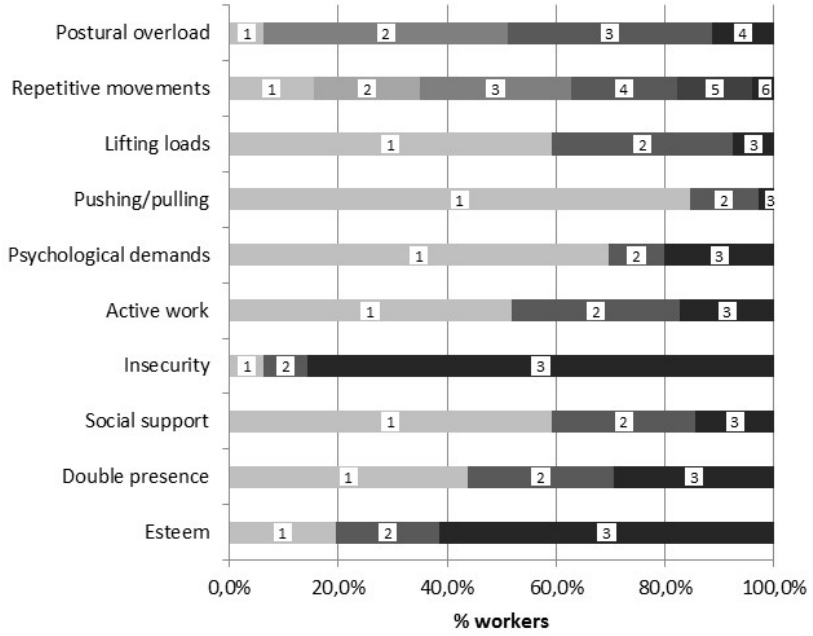

Figure 2. Distribution of risk levels according to factors evaluated

3.3 Relevant risk factors related to WMSDs

With the prevalence of WMSDs and the potential risk factors related to each worker and work, a matrix of 174 rows and 20 columns was constructed. The rows represent each worker consulted and the columns refer to the factors evaluated. These factors are: (1) postural overload, (2) repetitiveness, (3) lifts, (4) pushing / pulling, (5) psychological demands, (6) active work and developmental possibilities, (7) insecurity,) (9) social support and leadership quality, (9) dual presence, (10) esteem, (11) age, (12) gender, (13) body mass index, (14) smoking habit, (15) medical history related to musculoskeletal disorders, (16) frequency of household chores, (17) frequency of physical training, (18) time working at task, (19) overtime and (20) rotation between tasks.
However, it is expected that not all of these factors will have the same degree of correspondence with musculoskeletal discomfort, so the most relevant factors associated with WMSDs in each body region were identified. First, different subsets of factors were generated, according to two methods of attribute selection: *CfsSubsetEval* and *ConsistencySubsetEval* (available in *Weka*), which were combined with different search strategies such as: *BestFirst*, *ExhaustiveSearch*, *GeneticSearch*, *GreedyStepwise*, *LinearForwardSelection*, *RandomSearch*, *RankSearch*, *ScatterSearchV1*, and *SubsetSizeForwardSelection*.
Table 1 shows the results obtained from the application of the mentioned selection algorithms, on the data file, for the specific case of shoulder discomfort. As can be visualized, six different subsets were generated, ranging from 12 to 3 factors; being the most repetitive those identified with numbers 1, 2 and 18, this is postural overload, repetitiveness of movements and time working in the same task, respectively. Also the algorithms (selection method together with search strategy) that allowed to obtain each subset, are mentioned.

Table 1. Sub-sets generated for the shoulders discomfort

Subset	N° Factors	Factors	Algorithm
1	12	1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 17, 18	*ConsistencySubsetEval + RandomSearch*
2	9	1, 2, 4, 5, 8, 11, 12, 18, 19	*ConsistencySubsetEval + GeneticSearch*
3	6	1, 2, 4, 5, 12, 18	*ConsistencySubsetEval + BestFirst*
4	4	1, 2, 12, 18	*CfsSubsetEval + RandomSearch*
5	4	1, 2, 5, 18	*ConsistencySubsetEval + GreedyStepwise*
6	3	1, 2, 18	*CfsSubsetEval + BestFirst*

In order to decide which subset offers the highest correspondence with the prevalence of shoulder discomfort, the percentage of correctly classified instances (precision) was determined and compared using different classification methods (also available in *Weka*). The classification methods used include those based on: rules and decision trees, neural networks, logistic regression and Bayesian learning. In this way, the percentages of precision obtained for each subset of factors are given in Table 2, adding the alternative of considering the twenty original factors.

Table 2. Precision obtained with each subset of factors for shoulder discomfort

Alternative	Classifier (s)	Precision
All factors	*SimpleLogistic*	82,18 %
Subset 1	*RandomForest*	81,61 %
Subset 2	*NaiveBayes / Logistic / SMO / FT*	81,03 %
Subset 3	*RandomForest*	82,18 %
Subset 4	*RBFNetwork / SMO*	82,18 %
Subset 5	*FT*	**83,33 %**
Subset 6	*FT*	82,76 %

Therefore, the subset that allows to obtain the highest precision of classification of WMSDs of shoulders (83.33%) is given by factors 1, 2, 5 and 18 (subset 5), i.e., postural overload, repetitiveness of movements, the psychological demands and the time working at task.

In a similar way, the musculoskeletal discomfort reported in the region of the back, neck, hands/wrists, elbows/forearms, and legs/feet were analyzed.

Table 3 shows the factors that obtained the highest correspondence with the WMSDs of each part of the body analyzed. There can be observed that factors such as postural overload, repetitive movements, or medical history associated with musculoskeletal disorders are common for different affected body parts, while other factors such as insecurity, esteem, frequency of household chores or physical training are lacking of relevance for all the body parts considered.

Table 3. Relevant factors according to the affected body part

Attribute	WMSDs					
	Shoulders	Back	Hands	Neck	Legs	Arms
1. Postural overload	✓	✓	✓	✓		
2. Repeatability of movements	✓		✓	✓		
3. Lifting of loads		✓				
4. Pushing or pulling of loads		✓				✓
5. Psychosocial demands	✓			✓	✓	
6. Active work						
7. Insecurity						
8. Social support		✓				
9. Double presence						
10. Esteem						
11. Age						
12. Gender			✓			
13. Body mass index					✓	
14. Smoking habit						
15. Medical history		✓	✓			
16. Household chores			✓			
17. Physical training						
18. Time working at task	✓					
19. Overtime						✓
20. Rotation between tasks			✓			

4. Discussion

The prevalence of musculoskeletal discomfort in the meat industry workers found in this study (77%) is similar to that obtained in other investigations done in the industrial sector. Öztürk & Esin (2011) found an overall prevalence of 65% in sewing workers in a textile company, with the trunk (62.5%), neck (50.5%) and shoulders (50.2%). In the same way, Ilardi (2012) found a prevalence of 80% of hand and wrist WMSDs symptoms in workers of the salmon industry, specifically in bone work; followed by shoulders by 60% and arms/elbows by 50%. While the prevalence levels of WMSDs in the shoulders are similar in all three scenarios (between 50 and 60%), the most critical body parts differ between them. In the case presented here the most commonly affected part is the shoulders, while in the textile workers is the trunk and in the workers of the fish industry are the hands and wrists; however, the importance of WMSDs is indisputable.

According to the results found, the diversity of factors associated with the musculoskeletal discomfort of each body part confirm that the origin of the disease is multifactorial and complex, involving not only biomechanical, but also psychosocial and individuals factors.

In the case of shoulder discomfort, which is the body part that affects most workers (49.4%), it was determined that postural overload (biomechanical), repetitive movements (biomechanical), psychological demands (psychosocial) and the time working in the same task (individual) represents the subset of factors that correspond most to the occurrence of the disorder. Some investigations consulted (Bodín et al, 2012; Flores & Bastías, 2011 and Bernard, 1997) coincide to associate the biomechanical factors of postures and repetitiveness with the WMSDs of the shoulders, but they did not include psychosocial factors. However, in the study by Devereux, Rydstedt, Kelly, Weston & Buckle (2004), there was evidence of the relation between shoulder discomfort and psychosocial factors (low social support, low reward, ambiguity about the future of work), biomechanical factors (posture, repetitiveness and load lifting) and even individual (age and gender). Although they do not exactly match the ones found here, they confirm the multicausal origin.

After shoulders, the back is the body part that most affects the workers considered in the study with 47.1%. The factors related to this type of discomfort are biomechanical: postural overload, lifting of loads and activities of pushing or pulling, but also found an important relationship with the low social support (psychosocial) and the existence of a medical history associated with musculoskeletal disorders (individual). These results have a high coincidence with those found in other studies (Bernard, 1997; Meksawi, Tangtrakulwanich & Chongsuvivatwong, 2012; Tinubu, Mbada, Oyeyemi & Fabunmi, 2010; Camargo, Orozco & Herrera, 2008 and Elders & Burdorf, 2001) done in different occupational fields. They found a high correspondence between biomechanical risk factors (postures, lifting and manipulation of loads) and back discomfort. In relation to the psychosocial factors, some researchers like Widkstein et al (2012), Widanarko et al (2012) and Bongers, de Winter, Kompier & Hildebrandt (1993) found that the poor social support of supervisors and peers represents a contributing factor in back WMSDs, coinciding with this study.

In general, the results found could constitute the input for the construction of models that allow an explanation of the occurrence of WMSDs, as well as for the prediction of this type of disease that affects large numbers of workers, and in particular in meat processing industry. Prediction is the basis of effective prevention.

5. Conclusions

The most commonly affected body parts in the industrial sector studied were the shoulders and back, as reported by 86% and 82% of the workers consulted, respectively. Then follow the hands/wrists (55%), the neck region (51%), the lower extremities (39%) and the elbows/forearms (23%).

The most important risk factors associated with the presence of musculoskeletal discomfort reported by workers were identified, which corresponded not only to biomechanical variables, but also to psychosocial and individual variables. Shoulder discomfort were related to higher level of risk due to postural overload, a higher level of risk due to repetitive movements, more unfavorable exposures from the point of view of psychological demands, and greater time working at the position. Back discomfort were associated with higher levels of load manipulation (lifting and pushing or pulling), higher risk of postural overload, more unfavorable social support and the medical history related to musculoskeletal discomfort.

The biomechanical risk factor with the greatest impact on musculoskeletal discomfort was postural overload, being associated with the presence of discomfort at the shoulders, back, neck and hands. This risk factor represent the aspect that needs the most attention in the industrial sector considered. On the other hand, the psychological demands to which the worker is exposed was the psychosocial factor that was associated with a greater number of discomforts,

and therefore needs special attention. While the most relevant individual factor is the medical history of the worker related to his musculoskeletal system, which reflects the importance of recurrence of discomfort.
The preliminary results found in this study constitute an important source for preventive intervention processes at the industrial level and represent the basis for the construction of predictive models for the analysis of jobs with similar characteristics.

References

Almagro, B., Borrero, J., Paramio, G., Carmona, J., and Sierra, A., Trastornos musculoesqueléticos en el personal de administración y servicios de la Universidad de Huelva, *Revista Digital de Salud y Seguridad en el Trabajo*, vol. 1, pp. 1-20, 2009.

Attwood, D., Deeb, J., and Danz, M., *Ergonomic solutions for the process industries*, Elsevier, Burlington, 2004.

Bernard, B., *Musculoskeletal disorders and workplace factors*, National Institute for Occupational Safety and Health, Cincinnati, 1997.

Bodín, J., Ha, C., Petit, A., Sérazin, C., Descatha, A., Leclerc, A., Goldberg, M, and Roquelaure, Y., Risk factors for incidence of rotator cuff syndrome in a large working population, *Scandinavian Journal of Work, Environment and Health*, vol. 38, no. 5, pp. 436–446, 2012.

Bongers, P., de Winter, C., Kompier, M., and Hildebrandt, V., Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work, Environment and Health*, vol. 19, no. 5, pp. 297-312, 1993.

Camargo, D., Orozco, L., and Herrera, E., Dolor de cuello / hombros y espalda en adolescentes. Prevalencia y factores asociados, *Salud UIS*, vol. 40, no. 2, pp. 71-82, 2008.

Canadian Centre for Occupational Health and Safety, Work-related musculoskeletal disorders (WMSDs), Available: http://www.ccohs.ca/oshanswers/diseases/ rmirsi.html., 2014.

Chandna, P., Deswal, S., and Pal, M., Semi-supervised learning based prediction of musculoskeletal disorder risk. *Journal of Industrial and Systems Engineering*, vol. 3, no. 4, pp. 291-295, 2010.

Colombini, D., Occhipinti, E., and Grieco, A., *Risk assessment and management of repetitive movements and exertions of upper limbs*, Elsevier, Amsterdam, 2002.

Devereux, J., Rydstedt, L., Kelly, V., Weston, P., and Buckle, P., *The role of work stress and psychological factors in the development of musculoskeletal disorders, Health and Safety Executive Research Report 273*, HSE Books, Sudbury, 2004.

Elders, L., and Burdorf, A., Interrelations of risk factors and low back pain in scaffolders, *Occupational and Environmental Medicine*, 58, pp. 597–603, 2001.

Flores, R., and Bastías, M., Determinación de enfermedad profesional y estudio de puesto de trabajo, *Ciencia y Trabajo*, vol. 13, no. 39, pp. 36-43, 2011.

Hernández, R., Fernández, C., and Baptista, P., *Metodología de la investigación*, Mc Graw-Hill, México DF, 2010.

Ilardi, J., Relationship between productivity, quality and musculoskeletal disorder risk among deboning workers in a Chilean salmon industry, *Work*, vol. 41, pp. 5334-5338, 2012.

Instituto de Biomecánica de Valencia, IBV, *Ergo/IBV. Evaluación de riesgos ergonómicos*, Universidad Politécnica de Valencia., Valencia, 2011.

Instituto Sindical de Trabajo, Ambiente y Salud, ISTAS, *Manual del método CoPsoQ-istas21 (versión 1.5) para la evaluación y prevención de los riesgos psicosociales*, Centro de Referencia de Organización del Trabajo y Salud, Barcelona, 2010.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorensen, F., Andersson, G., and Jorgensen, K., Standardised nordic questionnaires for the analysis of musculoskeletal symptoms, *Applied Ergonomics*, vol. 18, no. 3, pp. 233-237, 1987.

McAtamney, L., and Corlett, N., RULA: a survey method for the investigation of work-related upper limb disorders, *Applied Ergonomics*, vol. 24, no. 2, pp. 91-99, 1993.

Meksawi, S., Tangtrakulwanich, B., and Chongsuvivatwong, V., Musculoskeletal problems and ergonomic risk assessment in rubber tappers: A community-based study in southern Thailand, *International Journal of Industrial Ergonomics*, vol. 42, pp. 129-135, 2012.

Organización Internacional del Trabajo, OIT, *La prevención de las enfermedades profesionales*, OIT, Ginebra, 2013.

Öztürk, N., and Esin, M., Investigation of musculoskeletal symptoms and ergonomic risk factors among female sewing machine operators in Turkey, *International Journal of Industrial Ergonomics*, vol. 41, pp. 585-591, 2011.

Punnett, L., and Wegman, D., Work-related musculoskeletal disorders: the epidemiologic evidence and the debate, *Journal of Electromyography and Kinesiology*, vol. 14, pp. 13-23, 2004.

Tinubu, B., Mbada, C., Oyeyemi, A., and Fabunmi, A., Work-related musculoskeletal disorders among nurses in Ibadan, south-west Nigeria: a cross-sectional survey, *BMC Musculoskeletal Disorders*, 11:12, 2010.

Universidad Politécnica de Valencia, UPV, NIOSH (Ecuación revisada de NIOSH), Available: http://www.ergonautas.upv.es/metodos/niosh/niosh-ayuda.php., 2006.

Widanarko, B., Legg, S., Stevenson, M., Devereux, J., Eng, A., Mannetje, A., Cheng, S., and Pearce, N., Gender differences in work-related risk factors associated with low back symptoms, *Ergonomics*, vol. 55, no. 3, pp. 327–342, 2012.

Witten, I., and Frank, E. *Data mining. Practical machine learning tools and techniques*. 2ª edición, Elsevier, San Francisco, 2005.

Biography

Mervyn Márquez is an Associate Professor of the Industrial Engineering Department, National Experimental University of Táchira (UNET), Venezuela. Coordinator of the Healthy Workplace Research Group, UNET. Industrial Engineer and Master of Science in Industrial Engineering, UNET. Doctor in Engineering, University of Carabobo, Venezuela. Certification in Ergonomics, University of Concepcion, Chile. His research interests include ergonomics, human factors, work design, and manufacturing systems.