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Errors using observational methods for ergonomics assessment in real practice

Jose-Antonio Diego-Mas[a*], Rocio Poveda-Bautista[b] and Jorge Alcaide-Marzal[a]

[a] *I3B, Institute for Research and Innovation in Bioengineering, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain.*
[b] *INGENIO [CSIC-UPV], Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain.*

* Corresponding author. Tel.:+34 963 877 000.
E-mail address: jodiemas@dpi.upv.es (J.A. Diego-Mas)

PRÉCIS/SHORT ABSTRACT: 442 musculoskeletal disorder risk assessments of actual jobs carried out by 290 professionals from 20 countries were analyzed to determine their reliability. Approximately one out of three assessments conducted by practitioners in actual work situations does not adequately evaluate the level of potential work-related musculoskeletal disorder risks.

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ABSTRACT

Objective: The degree in which practitioners use the observational methods for musculoskeletal disorder risks assessment correctly was evaluated.

Background: Ergonomics assessment is a key issue for the prevention and reduction of work-related musculoskeletal disorders in workplaces. Observational assessment methods appear to be better matched to the needs of practitioners than direct measurement methods, and for this reason, they are the most widely used techniques in real work situations. Despite the simplicity of observational methods, those responsible for assessing risks using these technics should have some experience and know-how in order to be able to use them correctly.

Methods: 442 risk assessments of actual jobs carried out by 290 professionals from 20 countries were analyzed to determine their reliability.

Results: The results show that approximately 30% of the assessments performed by practitioners had errors. In 13% of the assessments the errors were severe and completely invalidated the results of the evaluation.

Conclusion: Despite the simplicity of observational method, approximately one out of three assessments conducted by practitioners in actual work situations does not adequately evaluate the level of potential musculoskeletal disorder risks.

Application: This study reveals a problem that suggests that a greater effort is needed to ensure that practitioners possess better knowledge of the techniques used to assess work-related musculoskeletal disorder risks, and that laws and regulations should be stricter as regards qualifications and skills required by professionals.

KEYWORDS: job risk assessment; industrial/workplace ergonomics; human error analysis; measures; physical work

1. Introduction

One of the objectives of occupational ergonomics is to care for workers' health avoiding their exposure to risks factors for musculoskeletal disorders. Achieving this objective reduces work-related physical or psychological disorders. The ergonomics assessment of work places is a key issue for preventing or reducing ergonomics risk factors. In this sense, ergonomics assessment methods are the tools for acquiring relevant and reliable evidence on which to base recommendations for changes to preserve workers' health. Increasingly, experts and researchers are developing new and improved assessment methods to be used by practitioners in real work environments.

Different criteria can be used to classify the methods to assess risk factors for musculoskeletal disorders (MSDs). For example, the width of the field of application, the complexity of collecting the data required, how much invasive the measurement technique is or the qualification of the practitioner required to apply the method correctly (Beek & Frings-Dresen, 1998; Li & Buckle, 1999; Malchaire, 2011; Wells, Norman, Neumann, & Andrews, 1997). Direct measurement methods use sensors attached to the worker for the measurement of certain variables. Although these methods collect accurate data, they are invasive, require resources to cover the costs of maintenance and substantial initial investment for purchasing the equipment (Chiasson, Imbeau, Aubry, & Delisle, 2012). On the other hand, the recruitment of highly qualified personnel to ensure the efficient operation of the equipment is needed (David, 2005; Trask & Mathiassen, 2012). Researchers prefer to work with direct methods; however, these methods are not suitable for use in real work situations (Li & Buckle, 1999; Roetenberg, Baten, & Veltink, 2007). Observational methods (OMs) are based on direct observation of workers while performing their tasks. The practitioners collect the necessary data while observing the work carried out by the worker. After that, they use tables or equations to measure the risks related to ergonomics aspects of the tasks developed. OMs are usually easy to use, applicable to a wide variety of work situations at a comparatively lower cost and suitable for a large number of workers. For these reasons, OMs seem to be better adapted to the needs of practitioners who usually have limited resources and time and need techniques that allow them to set the priorities for intervention (David, 2005; Genaidy et al., 1994; Bao et al., 2009).

Despite the user-friendliness and simplicity of OMs over direct measurement methods, a certain level of experience and knowledge for their proper use is needed (OHSCO, 2008). For example, it is necessary to know what risk factor is being assessed and the particular conditions of the task under analysis for the correct selection of the most suitable assessment method. Moreover, knowledge about the degree of accuracy and reliability of the selected method and ability to correctly interpret the results are needed. Previous studies, workshops and discussions with practitioners (Buckle & Li, 1996; David, 2005; David, Woods, Li, & Buckle, 2008; Diego-Mas, Poveda-Bautista, & Garzon-Leal, 2015; Li & Buckle, 1999, 2000; Malchaire, 2011) led to the identification of the most important issues that need to be addressed for the correct operation of OMs. Training level and skills for applying these techniques, and difficulties finding reliable information about OMs, were some of the most important issues found. Although the knowledge and skills required differ depending on the method used (Takala et al., 2010), many countries current regulations do not guarantee that practitioners have the necessary qualifications to properly apply OMs. For example, the legislation of many European and American countries does not demand of companies that people responsible for carrying out risk assessments have specific training or qualifications. In some cases, the only requirement is to possess very basic training.

Therefore, in many cases the practitioners do not have the necessary training recommended for the correct use of ergonomics analysis tools or to correctly interpret the results obtained from their use. In Diego-Mas et al. (2015) 267 practitioners from companies with more than 10 employees who regularly conduct ergonomics assessments were interviewed. About 81.56% indicated that they had official qualifications or certifications enabling them to carry out tasks relating to ergonomics and occupational risk prevention in their companies; whereas 18.44% responded that they had no such certification. When asked whether they considered that they had enough training in ergonomics risk assessment to carry out their tasks appropriately, 59.84% responded affirmatively, whereas 40.16% did not believe that they had enough training. In many cases, practitioners solve these problems through self-training and searching for the necessary information. However, another problem detected is that finding original or reliable information on a particular method can be difficult. Practitioners may lack the means required to access these resources. Therefore, practitioners obtain the information from other sources that provide incomplete or incorrect data. This problem is especially important for practitioners who do not speak English because the sources of the original information are usually written in English.

The aforementioned studies indicate that, on the one hand, OMs are the most commonly used techniques to conduct ergonomics assessments by practitioners, but on the other hand, the level of training of practitioners in ergonomics may be insufficient to correctly apply the OMs. Therefore, to what extent can the lack of training of practitioners be the cause of unreliable conclusions when they use OMs to assess the risk of work related MSDs? The main objective of this work is to determine if assessments of MSDs risk factors conducted in companies using OMs are performed correctly or, conversely, the lack of specialized training or experience of practitioners may result in unreliable assessments. Knowing if OMs are correctly used in actual practice is important because these techniques are the first and most common tools to prevent the workers being exposed to risk factors for musculoskeletal disorders.

In the present work, the application process and the results of 442 ergonomics assessments of real workplaces were reviewed looking for errors. There are many MSDs risk factors and many OMs to assess them; therefore, it is very difficult to include all of them in a single study. Our work was focused on physical risk factors and associated OMs. To select them we followed the results found in Diego-Mas et al., 2015 about the OMs most commonly used in real practice.

2. Methods

Developing this study required ergonomics assessments of actual workplaces performed by practitioners. The ergonomics assessment reports were obtained using the website *Ergonautas*. *Ergonautas* is a web platform (http://www.ergonautas.upv.es) managed by the team who carried out this research. It mainly aims to provide online information and software in the Spanish language for applying tools and techniques commonly used for the ergonomics assessment of workplaces. When this work was performed, the platform had over 105,000 registered users from 60 different countries. About 8,000 of them had a professional user registration. Professional users pay for the registry and have access to advanced tools and online software, while the standard registration is free and provides limited access. Upon registration, professional users should complete a personal profile form in which information about their tasks, qualifications and companies is collected.

2.1 Selection of practitioners

The web platform database was used to analyze the profiles of the registered professionals. Professionals who had not logged into the web platform in the past 6 months were excluded. Finally, a list of 1624 users who were registered as professionals from companies with more than 10 employees, and who had carried out ergonomics assessments using the platform software was obtained.

An email was sent to the candidates containing information regarding the study and instructions on how to participate. By agreeing to participate in the study, practitioners gave permission to store their ergonomics assessment reports on the platform server, and accepted to provide additional information and answer any further questions when required by the research team. Confidentiality of the personal information and the name of the companies involved in the study was granted. Participants in the study were rewarded with a free renewal of their registrations on the web platform. Responses were obtained from 645 professionals. 92 respondents were excluded because their profiles or jobs were different to those stored in the web platform due to recent changes. Finally, a list of 553 participants was obtained.

2.2 Selection of observational assessment methods

The observational assessment techniques used in this work were selected based on the results of the research conducted in Diego-Mas et al. (2015). The selected methods were as follows: National Institute for Occupational Safety and Health lifting equation (NIOSH) (Waters, Putz-Anderson, Garg, & Fine, 1993); Snook and Ciriello tables of Maximum Acceptable Weights and Forces (Snook & Ciriello, 1991); Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000); Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993); Owako Working Posture Assessment System for posture assessment (OWAS) (Karhu, Kansi, & Kourinka, 1977); Job Strain Index (JSI) (Moore & Garg, 1995); Occupational Repetitive Action (OCRA) (Occhipinti, 1998); OCRA Checklist for repetitive movements assessment (Colombini, Occhipinti, Cairoli, & Barracco, 2000); Laboratoire d’economie et de sociologie du travail (LEST) (Guelaud, Beauchesne, Gautrat, & Roustang, 1977) and Chaffin Biomechanical Model (BiomechEEC, a computerized biomechanical model based on the proposal in Chaffin (1969)).

Ergonautas provides online applications for the different OMs listed above. Each time a participant in the study completed an ergonomics assessment form with these applications, the record of accesses was updated and the assessment data was stored on the server.

2.3 Study development

The review team consisted of the authors of this work and ten ergonomics professionals. All of them had long experience with MSDs prevention and observational assessment techniques. The process began with several meetings in which the review team discussed the most convenient revision process and the classification of errors. The team determined how to analyze the ergonomics assessments conducted by practitioners looking for possible errors. Three categories of errors were identified, namely: *Severe Errors*, *Moderate Errors* and *Application Errors*.

Severe errors are conceptual errors that completely invalidate assessment reliability. This kind of errors indicates that the practitioner does not know how to use the method or applies it inappropriately. Examples of errors that fall into this category are using a method for assessing a risk factor for which it was not designed (for example, using the NIOSH lifting equation to assess worker postures) or improperly applying the method (for example, mixing data from both sides of the body to apply the RULA method). *Moderate errors* are errors that cause estimating the ergonomics risk incorrectly. In this case, the selection of the assessment method is appropriate and the task being assessed fulfils the required specifications, but the misapplication of the tool results in an improper assessment of the risk (e.g. errors in working posture coding from visual observations when using OWAS). Finally, *Application errors* are specific errors due to carelessness and not to lack of knowledge or training (e.g. errors in calculations or data typing errors using the software).

When one participant completed an ergonomics assessment form on the web platform, all data was stored in the server and the assessment was analyzed by one member of the review team. The assessment form comprises the numerical data required for the calculations, the images, observations and descriptions made by the professional. Additionally, when the reviewer considered that more information was needed to clarify some specific aspect of the assessment, he contacted the practitioner asking for additional information, such as images or further details about the way the evaluation was performed. When an error was identified in the assessment form, the reviewer decided whether it was classified as a severe, moderate or application error. In many cases, the reviewer contacted the practitioner again to know whether the error was due to lack of knowledge or if it was a punctual mistake. If the error found was considered to be severe, the reviewer coded the assessment as “with severe errors” and did not go on with the analysis process. When a moderate or application error was detected, the reviewer analyzed the assessment form comprehensively for the identification of more errors. After the revision, if moderate and application errors were detected in an assessment form, it was classified as “with moderate errors”. If only minor errors were detected then the form was recorded as “with application errors”. If no errors were detected the form was coded as “without errors”. In a second revision stage, each reviewer in charge showed the errors found in their revised assessments to the review team. If errors were found in the assessment, the team analyzed them and confirmed the degree of severity assigned. If no errors were detected in an assessment, it was revised by the team looking for undetected errors.

2.4 Data analysis

A descriptive statistical analysis was carried out on the errors detected in the 442 ergonomics assessments revised. A secondary descriptive statistical analysis was performed on the demographic data of the practitioners.

3. Results

Ergonomics assessments were received from 317 practitioners. Given that the number of practitioners invited to take part in this study was 553, the response rate was approximately 57.3%. Each participant sent between 1 and 6 ergonomics assessments, finally receiving 474 assessments. The first ergonomics assessment was revised in July 2013 and the last one in September 2015.

For a given OM to be included in the study, at least 15 assessments should have been received from practitioners using that OM. 32 assessments were eliminated from the study because the OM used was not implemented in at least 15 forms. Therefore, 442 assessments were analyzed and 290 practitioners remained in the process. Figure 1 shows the demographic and professional profile of these practitioners, and Table 1 presents the distribution by country and the distribution of participants by number of assessments submitted for review. No significant correlations were found amongst years of experience, age, sex, or country and the number of errors in the assessments performed.

Figure 1. Gender, age and years of experience of the participants in the survey

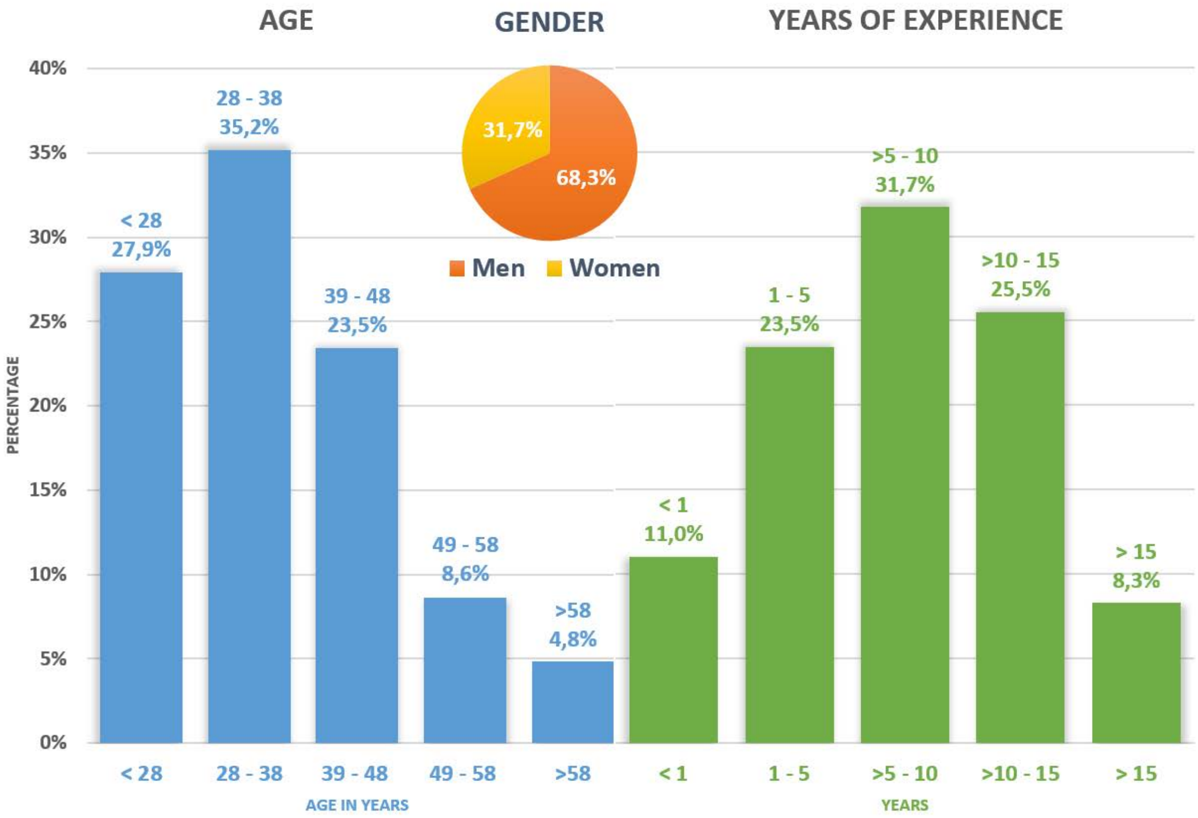

Table 1. Participants and assessments by country and number of assessments by participant.

Country	**Participants**							**Assessments**
	Total	Number of assessments sent for review						
		1	2	3	4	5	6	
Spain	103 35.5%	78	12	8	4	1	0	147 33.3%
Colombia	44 15.2%	32	7	3	1	0	1	65 14.7%
Mexico	36 12.4%	24	6	3	2	1	0	58 13.1%
Chile	22 7.6%	15	5	2	0	0	0	31 7.0%
Argentina	17 5.9%	12	4	1	0	0	0	23 5.2%
Venezuela	16 5.5%	10	4	1	0	0	1	27 6.1%
U.S.A	10 3.4%	6	3	0	1	0	0	16 3.6%
Peru	9 3.1%	5	2	0	1	1	0	18 4.1%
Ecuador	8	6	2	0	0	0	0	10

	2.8%							2.3%
Costa Rica	4 1.4%	3	1	0	0	0	0	5 1.1%
Guatemala	2 0.7%	2	0	0	0	0	0	2 0.5%
Others	19 6.6%	9	4	3	1	2	0	40 9.0%
Total	290	202	50	21	10	5	2	442

Although initially 10 OMs were included in the study, those of them not employed in at least 15 assessments forms were eliminated; therefore, finally only 6 OMs (Table 2) were taken into consideration in the analysis. As noted above, errors detected by the team were classified into three categories. Each error detected was assigned a code; the first two characters of the code indicate the OM used, the third character indicates the category of error (S: Severe error, M: Moderate error and A: Application error) and the fourth character is a number indicating the order within its category. Appendix 1 presents the list of errors by OM indicating error category, code and description.

No errors were detected in 69.7% of the reviewed assessments; 13.3% of the assessments had Severe Errors; 15.2% had Moderate Errors and 1.8% had Application Errors (Figure 2). It should be remembered that if a Severe Error was detected in an assessment form, the reviewer coded the assessment as “with severe errors” and did not go on with the analysis process. Table 2 shows the number of errors found in the assessment forms for each OM and error category.

Figure 2. Percentage of assessments with errors and category of error.

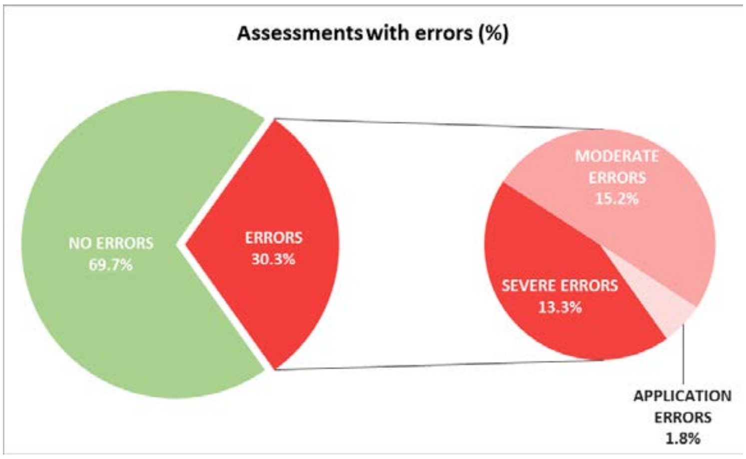

Table 2. Errors and category of error by method

Method	Reviewed cases	Without errors	With Errors	Type of error		
				Severe	Moderate	Application
RULA	82	60 73.17%	22 26.83%	8 9.76%	13 15.85%	1 1.22%
OWAS	72	63 87.5%	9 12.5%	3 4.17%	4 5.56%	2 2.78%
REBA	66	47 71.21%	19 28.79%	4 6.06%	13 19.70%	2 3.03%
NIOSH lifting equation	112	65 58.03%	47 41.96%	24 21.43%	22 19.64%	1 0.89%
OCRA Checklist	62	39 62.9%	23 37.10%	12 19.35%	9 14.52%	2 3.23%
BiomechEEC	48	34 70.83%	14 29.17%	8 16.67%	6 12.50%	0 0%
Total	442	308 69.68%	134 30.32%	59 13.35%	67 15.16%	8 1.81%

Table 3 shows what errors (indicated by their error codes) were detected by OM. For a detailed description of the errors see Appendix 1. This table also shows the percentage of assessments by OM and category of error detected. If we consider all the reviewed assessments, the most frequent error occurs when using the NIOSH lifting equation to assess lifting tasks in which the worker carries the load over long distances. A chi-squared test (Chi-squared = 22.54, df = 5) was performed to compare the observed proportions of assessment with errors by OM, finding that there were significant differences amongst methods (p = 0.0004) with a confidence level of 95%. An analysis of means with the same confidence level (ANOMS, UDL=0.41, LDL=0.16) showed that the proportion of assessment with errors was significantly lower than average on OWAS (proportion=0.0972) and higher on NIOSH lifting equation (proportion=0.4107). In these analyses, only severe and moderate errors were considered.

Table 3. Class and frequency of errors by method

Method	Class of error	Error code[1]	Frequency	Percentage
RULA	Severe	RU S1	4	4.88%
		RU S2	2	2.44%
		RU S3	2	2.44%
	Moderate	RU M1	6	7.32%
		RU M2	5	6.10%
		RU M3	2	2.44%

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[1] See Appendix 1 for a detailed description of the errors.

	Application	RU A	1	1.22%
REBA	Severe	RE S1	1	1.52%
		RE S2	1	1.52%
		RE S3	2	3.03%
	Moderate	RE M1	4	6.06%
		RE M2	5	7.58%
		RE M3	3	4.55%
		RE M4	1	1.52%
	Application	RE A	2	3.03%
NIOSH lifting equation	Severe	NI S1	4	3.57%
		NI S2	8	7.14%
		NI S3	2	1.79%
		NI S4	4	3.57%
		NI S5	2	1.79%
		NI S6	4	3.57%
	Moderate	NI M1	5	4.46%
		NI M2	6	5.36%
		NI M3	3	2.68%
		NI M4	5	4.46%
		NI M5	3	2.68%
	Application	NI A	1	0.89%
OWAS	Severe	OW S1	1	1.39%
		OW S2	1	1.39%
	Moderate	OW M1	2	2.78%
		OW M2	1	1.39%
		OW M3	1	1.39%
	Application	OW A	2	2.78%
OCRA Checklist	Severe	OC S1	3	4.84%
		OC S2	4	6.45%
		OC S3	2	3.23%
		OC S4	3	4.84%
	Moderate	OC M1	2	3.23%
		OC M2	3	4.84%
		OC M3	1	1.61%
		OC M4	3	4.84%
	Application	OC A	2	3.23%
BiomechEEC	Severe	BI S1	5	1.42%
		BI S2	3	6.25%
	Moderate	BI M1	2	4.17%
		BI M2	3	6.25%
		BI M3	1	2.08%
	Application	BI A	0	0%

4. Discussion

317 practitioners from 20 different countries took part in this study, being, to the best of our knowledge, the most comprehensive survey about the use of OMs in real practice. The target population in this research were practitioners from companies with more than 10 employees who regularly conduct ergonomics evaluations. Considering an infinite population and a simple random sample, the maximum margin of error is 0,057 at 95% confidence level. Respondents were selected among the users of a web platform focused on ergonomics assessment methods registered as professionals. Whether these users are representatives of the global population will be discussed later in this section.

The results show that approximately 30% of the assessments performed by practitioners had errors. In 13% of the assessments the errors were severe and completely invalidated the results of the evaluation. In 15% of cases the errors caused an overestimation or underestimation of the MSDs risk in the task under assessment. Approximately 2% of the assessments had errors due to carelessness. The procedure followed in the analysis of errors only took into consideration one Severe Error per assessment although there were more errors. Additionally, the team might not have detected the occurrence of some errors in their analysis of the assessment forms; therefore, the values obtained are lower bounds of the actual percentage of assessments with errors. The conclusion is that at least 30% of the reviewed assessments had errors of diverse severity.

The demographic and professional profile of the participants (years of experience, age, sex, or country) does not seem to influence the quality of the evaluations performed. It is noteworthy to mention the high number of assessments using the NIOSH lifting equation and OCRA Checklist that contained severe errors (21.45% and 19.35%). On the other hand, practitioners commit less severe errors using OWAS (12.5%). The statistical analysis performed, comparing the observed proportions of assessment with errors by method, found that using the NIOSH lifting equation errors were more likely to be committed. Conversely, the proportion of errors using the OWAS method was significantly lower.

The results of this study are disturbing. Approximately one out of three assessments conducted by practitioners in actual work situations does not adequately assess the level of potential MSDs risk. The assessment of work places plays a central role in preventing or reducing risk factors for musculoskeletal disorders. For practitioners, OMs are the most widely used tools for acquiring relevant and reliable evidence on which to base recommendation for changes to preserve workers' health (David, 2005; Genaidy et al., 1994; Bao et al., 2009). Therefore, the fact that 30% of the assessments had some kind of error is a matter for serious concern. The efforts of researchers and experts to develop new and improved assessment methods to be used by practitioners in real work environments can be ineffective and useless if these tools are not properly used in practice.

In 28% of the assessments, the errors found were caused by lack of knowledge or improper use of the OMs (severe and moderate errors). The results suggest that more effort is needed to ensure that practitioners possess better knowledge of OMs and tools used to assess work-related musculoskeletal disorder risks. In many cases, current national regulations do not demand specific qualifications to be in charge of these tasks. Perhaps, stricter laws and regulations relative to the skills and qualification of ergonomics practitioners will be necessary. From the data collected in this survey, it has not been possible to find significant correlations between the years of experience in ergonomics assessment and errors committed. Although more research in this regard is still needed, the fact that more experience does not entail fewer errors may suggest that the lack of knowledge about the methods employed does not diminish over time, and that refresher courses would be necessary to improve the results.

The high number of errors detected shows that the analyzed OMs require some ergonomics knowledge and, regrettably, it suggests that practitioners' curricula have not enough ergonomics content to apply them properly. Therefore, practitioners must consider the complexity and the required training level when they select the adequate technique. On the other hand, to perform an assessment correctly a detailed understanding of how the job is done and all the tasks and subtasks involved is needed. It is necessary to ensure that there is agreement on which MSD hazards need to be assessed, the body parts affected, and the tasks or subtasks that should be investigated. Finally, it is necessary to identify the potential risk assessment methods that meet the criteria agreed in the previous steps (OHSCO, 2008). The analyst should select a method based on the reliability, validity, practicality, and purpose of the risk assessment (Takala et al., 2010). The inability of the tools selected by practitioners to adequately represent the assessed tasks may lead to some of the errors observed. As was concluded in Pascual and Naqvi (2008), ergonomic checklists require the least effort by the evaluators and help to gather basic information about a job. Consequently, improved checklists that are more task specific will help practitioners to better identify ergonomics risk, and OM's should only be used if an in-depth risk assessment is really needed.

It is necessary to make some considerations regarding this study. Although there are more accurate and reliable risk assessment techniques, in the present study only OMs were taken into consideration. Although direct measurement or instrument-based methods are more reliable and accurate, and they are usually preferred by researchers, using these techniques implies problems that make its use in real work environments difficult (Li & Buckle, 1999). OMs appear to be best matched to the needs of practitioners (David, 2005; Genaidy et al., 1994) and hence they are the most widely used in real work situations. On the other hand, there is a wide range of OMs and, therefore, it is very difficult to include all of them in a single study. The OMs initially included in this survey were those most commonly used according to the study by Diego-Mas et al., 2015; however some OMs were eliminated of the present analysis because they were received in an insufficient number (at least 15 assessments were required to consider the results as being significant). Finally, six OMs representative of those most commonly used by practitioners were analyzed.

Another limitation of this study is related to the participants in the survey. We obtained responses from 317 practitioners from 20 different countries, however, all of them were Spanish speakers and, with some exceptions, they lived in Spanish speaking countries. Language can be a drawback for self-training and information search. Usually, researchers who develop assessment methods publish their findings in English in scientific journals, and most of technical reports available on the Internet are written in this language. This can be a difficulty for practitioners who do not speak English, since the original information sources are usually in this language. On the other hand, all the professionals who participated in this study employed software for the ergonomics assessments. The use of specific software for the application of OMs helps practitioners to perform calculations and, therefore, it reduces human mistakes. The results would probably differ if assessments were performed without computer aid.

Finally, some standards, such as EN 1005-2 and ISO 11228, have introduced relaxations in the conditions in which some methods can be used. For example, according to EN 1005-2, the NIOSH lifting equation can be used to assess one-handed lifting or lifting carried out by several workers. In the same way, the ISO 11228 standard considers it acceptable to assess lifting tasks carrying the load over a long distance. Therefore, in the context of these standards, errors like NI S2 or NI S4 can be considered acceptable. However, in this study, the original conditions for the applicability of each method has been assumed. Similarly, the biomechanical model used in the BiomechEEC method is intended to assess static strengths. However, in some circumstances (slow movements) this method can be used to evaluate dynamic situations. During the revision of the assessments, applying BiomechEEC in a dynamic task has been considered an error, unless its applicability to that task had been justified.

5. Conclusions

The main objective of this study was to determine to what extent the assessment of risk factors for musculoskeletal disorders conducted in companies by practitioners using OMs are performed correctly or, conversely, if the lack of training or experience of professionals could be a cause of errors in the implementation of the assessments. The results show that about 30% of the analyzed assessments had errors. In 13% of the assessments the errors were severe and completely invalidated the results. In 15% of cases the errors caused an overestimation or underestimation of the risk in the workplace. Approximately 2% of the assessments had errors due to carelessness.

The results suggest that a greater effort is needed to ensure that practitioners possess a better knowledge of the techniques used to assess MSD risks, and that the laws and regulations of the different countries should be stricter as regards qualifications and skills required of professionals. On the other hand, practitioners must consider the complexity and the required training level when they select the adequate technique.

Key points

- 442 risk assessments of actual workplaces carried out by 290 professionals from 20 countries were analyzed to determine their reliability.
- Approximately 30% of the assessments had errors. 13% of the errors invalidated the results of the evaluation. 15% of the errors caused a miss estimation of the risk.
- The results suggest that a greater effort is needed to ensure that practitioners possess a better knowledge of the techniques used to assess risk factors for musculoskeletal disorders.
- Practitioners must consider the complexity, the required training level, and the suitability when they select the adequate technique.

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Biographies

Jose Antonio Diego-Mas is full professor in the Department of Engineering Projects and researcher in the Institute for Research and Innovation in Bioengineering (i3B) of the Universidad Politecnica de Valencia (UPV). He received his PhD in industrial engineering from UPV, Spain, in 2006.

Rocio Poveda-Bautista is full professor in the Department of Engineering Projects and researcher in INGENIO, a joint research institute of the Spanish National Research Council (CSIC) and the UPV. She received her PhD in industrial engineering from UPV, Spain, in 2007.

Jorge Alcaide-Marzal is full professor in the Department of Engineering Projects and researcher in the Institute for Research and Innovation in Bioengineering (i3B) of the UPV. He received his PhD in industrial engineering from UPV, Spain, in 2004.

Appendix 1. Errors

Errors detected in the use of the RULA method (error class and description).

Class of error	Error Code	Description
Severe Errors	RU S1	Using the method for assessing a risk factor for which it was not designed.
	RU S2	Using together data of both sides of the body (RULA evaluates a single body side: left or right).
	RU S3	Using data from various body postures (RULA evaluates only one posture).
Moderate Errors	RU M1	Incorrect measurement of angles between body members due to misusing the references defined by the method (e.g. bending angle of the trunk measured from a reference other than the vertical axis).
	RU M2	Angle measurements on photographs of workers which do not clearly show the angles between the members of the body, or when the angles are showed in inadequate perspective.
	RU M3	Errors in coding body postures, sustained loads or type of muscular activity. (e.g. not considering that if the forearm crosses the center line of the body the forearm score should be increased by one point).
Application errors	RU A	Errors in the use of software, incorrect calculations, errors when changing measurement units…

Errors detected in the use of the REBA method (error type and description).

Class of error	Error Code	Description
Severe Errors	RE S1	Using the method for assessing a risk factor for which it was not designed.
	RE S2	Using together data of both sides of the body (REBA evaluates a single body side: left or right).
	RE S3	Using data from various body postures (REBA evaluates only one posture).
Moderate Errors	RE M1	Incorrect measurement of angles between body members due to misusing the references defined by the method.
	RE M2	Angle measurements on photographs of workers which do not clearly show the angles between the members of the body, or when the angles are showed in inadequate perspective.
	RE M3	Errors in coding body postures, sustained loads or type of muscular activity.
	RE M4	Misapplication of the Gravity Assisted condition.
Application errors	RE A	Errors in the use of software, incorrect calculations, errors when changing measurement units…

Errors detected in the use of the NIOSH Lifting Equation method (error class and description).

Class of error	Error Code	Description
Severe Errors	NI S1	Using the method for assessing a risk factor for which it was not designed.
	NI S2*	Carrying a load over a long distance or heavy load pulling or pushing when these activities are important in respect to the assessed load lifting (the equation should only be used if the activity that accompanies load lifting is no more than 10% of the worker's activity).
	NI S3	Prolonged sitting or kneeling periods.
	NI S4*	Manual handling operations with one hand or by several workers.
	NI S5	Multi-task analysis of non-alternating tasks (multitasking analysis applies when load-lifting conditions vary and are performed alternately. e.g. different heights or different load weights).
	NI S6	Analyzing several simple tasks as multitasking load lifting.
Moderate Errors	NI M1	Other unfulfilled conditions relative to the use of the method (e.g. the knee flexion is greater than 15° when lifting a load, the load is unstable, or with unstable center of gravity).
	NI M2	Erroneous measurements of distances or angles (e.g. incorrect measurement of the asymmetry angle due to using wrong reference points).
	NI M3	Not considering significant load control at the destination point (if there is significant load control at the end of the lifting, the task should be assessed both at the beginning and end of the movement by applying the NIOSH equation twice).
	NI M4	Misinterpretation of body recovery times (e.g. to calculate the Frequency Multiplier the period of time the worker is engaged in other tasks not involving load handling should be considered).
	NI M5	Misinterpretation of the coupling or quality of the workers grip on the object (error in determining the value of the Coupling Multiplier depending on whether the load has a gripping system, the position of the fingers of the worker or the volume and shape of the object).
Application errors	NI A	Errors in the use of software, which are not due to errors in the selection or application of the method, errors when changing measurement units…

(*) The standards EN 1005-2 and ISO 11228 have introduced some relaxations in the conditions in which NIOSH Lifting Equation can be applied. In the context of these standards, tasks in which the load is carried a long distance or handled with one hand are suitable for this method under some conditions. In this work, practitioners used the NIOSH equation out of the context of EN 1005-2 and ISO 11228 standards. Therefore, NI S2 and NI S4 have been considered severe errors.

Errors detected in the use of the OWAS method (error class and description).

Class of error	Error Code	Description
Severe Errors	OW S1	Using the method for assessing a risk factor for which it was not designed.
	OW S2	Inadequate sampling frequency (very infrequent, irregular ...). In a sample of 100 observations the estimated error is about 10%, whereas for 400 observations the error decreases to about half (5%).
Moderate Errors	OW M1	Using videos or images from viewpoints that prevent observing the posture of the worker's body and the correct coding of body postures.
	OW M2	Miscoding of body postures or sustained loads from observations.
	OW M3	Misinterpretation of the health risk categories from the relative frequencies of each body posture.
Application errors	OW A	Errors in the use of software, errors due to incorrect calculations, errors when changing measurement units…

Errors detected in the use of the OCRA Check List method (error class and description).

Class of error	Error Code	Description
Severe errors	OC S1	Using the method for assessing a risk factor for which it was not designed.
	OC S2	Incorrect calculation of breaks and non-repetitive tasks in calculating the net time of repetitive work.
	OC S3	Using mixed-up data from both sides of the body (posture Factor must be calculated with data from one side of the body, left or right).
	OC S4	Assessments in which the worker performs several tasks as if it were a unique task (when the worker performs several tasks, the risks of each individual task weighted based on the time the worker spends in performing each task must be analyzed).
Moderate errors	OC M1	Incorrect calculation of recovery periods (e.g. the time spent on non-repetitive tasks should be considered as recovery period).
	OC M2	Errors in Technical Actions performed in the task (a Technical Action is a movement or movements necessary to complete a simple operation, e.g. moving, reaching, grasping an object with the hand or fingers, etc.).
	OC M3	Do not consider additional risk factors: exposure to cold, wearing gloves, injuries from tool operation, vibrations ...
	OC M4	Errors in the calculation of the cycle time (mainly by using the number of pieces produced to estimate the total number of cycles when several pieces are produced per cycle).
Application errors	OC A	Errors in the use of software, errors due to incorrect calculations, errors when changing measurement units…

Errors detected in the use of the BiomechEEC method (error class and description).

Class of error	Error Code	Description
Severe errors	BI S1	Non-static effort (the posture of the worker must be static, the model used by the method does not consider load inertia or significant accelerations).
	BI S2	Non-coplanar effort (the model used by the method does not consider torques in the sagittal plane of the worker).
Moderate errors	BI M1	Load generates torques in the body (the model used by the method considers that the load should not generate torques in the body).
	BI M2	Body parts included in the analysis lie on an object (the model considers that only the feet should be in contact with the ground).
	BI M3	Inaccurate measurement of the anthropometric dimensions (the human model employed by the method consists of 16 segments).
Application errors	BI A	Errors in the use of software, errors due to incorrect calculations, errors when changing measurement units…