International Journal of Industrial Ergonomics xxx (2017) 1–10

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Beyond OCRA: Predictive UL-WMSD risk assessment for safe assembly design

Guido J.L. Micheli*, Luca M. Marzorati

Politecnico di Milano, Department of Management, Economics and Industrial Engineering, Piazza Leonardo da Vinci 32, 20133 Milan, Italy

ARTICLE INFO

Article history:
Received 9 January 2016
Received in revised form
2 June 2017
Accepted 3 July 2017
Available online xxx

Keywords:
Safety
Upper-limb work-related musculoskeletal disorders
UL-WMSD
OCRA index
Assembly
Design

ABSTRACT

In terms of occupational safety, one of the most important areas to consider is that of Upper-Limb Work-related MusculoSkeletal Disorders (UL-WMSDs), i.e. work-related disorders due to biomechanical overload of the upper limbs caused by protracted movements and/or repeated efforts throughout the workday. To estimate the risk associated with these disorders, the method known as the OCRA (OCcupational Repetitive Actions) Index is universally accepted; based on observation, it provides an index whose value is related to the expected percentage of pathological cases among the entire working population. This work introduces a different perspective to the problem in order to provide designers with a method – PRASAD: Predictive Risk Assessment for Safe Assembly Design – that makes them aware of the issues related to UL-WMSDs, starting from the earliest stages of the design of a new product and the related assembly workstation, well earlier than observing the activities associated to its production, that is when the assembly workstation is fully set and running. The main advantage of the method lies in the outcome, the PRASAD Index, which is fully comparable with the OCRA Index, so that the proposal leverages on the well-known OCRA standard approach. The new method, aimed at a use in the design phase (of a new workstation for a new product), is potentially useful for a conventional risk assessment of existing workstations as well: it combines the rapidity of a checklist for the initial screening with a level of detail that is characteristic of advanced methods, such as the OCRA Index. Finally, PRASAD represents an innovation in the risk assessment of UL-WMSDs because of its feature of modelling the concept of "Technical Actions", which enables estimating (and taking into account) the repetitiveness of tasks, based on technical design and production management data.

1. Introduction

With the evolution of the study of safety and the introduction of new norms, analysis of the evaluation of risk is becoming more and more important. Among the various fields of study related to workplace safety, the interaction between workers and the workplace plays a fundamental role. This problem can be decomposed into a myriad of aspects, one of which is the object of this text: the study of the risk of biomechanical overload of the upper limbs, which is the cause of certain diseases, defined as UL-WMSDs (upper-limb work-related musculoskeletal disorders) (Simoneau et al., 2003). At the same time, there has been a proliferation of different methods designed to estimate the associated risk (as further developed in the following).

This interest in these issues is now widespread internationally and is motivated by the continuous increase in work-related musculoskeletal disorders of the upper limbs: to quantify this increase, we have collected data regarding occupational diseases reported by INAIL (the Italian Workers' Compensation Authority) in Italy (INAIL, 2013) (Fig. 1, which shows the number of occurred, not necessarily compensated, work-related diseases). The trend is towards a substantial increase in general, and as for UL-WMSDs in particular. This is the reason for the increasing importance of methods that enable the assessment of the risk of contracting these pathologies.

It is also important to know that there are legal requirements that force owners/managers to intervene in matters of safety to ensure the health of the workers. In Italy, the "*Testo Unico*" in matters of safety, issued through Legislative Decree 81/08, is the reference legislative decree that must also be observed for the prevention of UL-WMSDs. It provides, in art. 15 (Legislative Decree 81/08, 2008), that the employer takes general measures for the

* Corresponding author.
E-mail address: guido.micheli@polimi.it (G.J.L. Micheli).

http://dx.doi.org/10.1016/j.ergon.2017.07.005
0169-8141/

Please cite this article in press as: Micheli, G.J.L., Marzorati, L.M., Beyond OCRA: Predictive UL-WMSD risk assessment for safe assembly design, International Journal of Industrial Ergonomics (2017), http://dx.doi.org/10.1016/j.ergon.2017.07.005

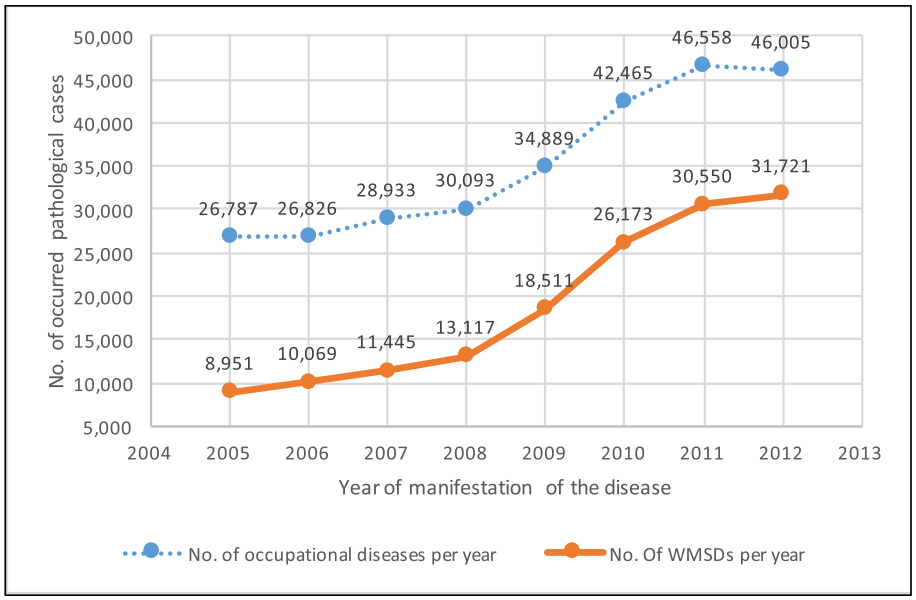

Fig. 1. Number of occurred (not necessarily compensated) work-related diseases (particularly musculoskeletal ones) reported by INAIL in Italy for all working areas from 2005 to 2012.

protection of workers, which include:

> *"… il rispetto dei principi ergonomici nella concezione dei posti di lavoro, nella scelta delle attrezzature e nella definizione dei metodi di lavoro e produzione, anche per attenuare il lavoro monotono e ripetitivo."*

(that is) … the respect of ergonomic principles in the conception of the workplace, in the selection of the equipment and in the definition of the methods of work and production, as well as the minimization of monotonous and repeated jobs.

Article 28 (Legislative Decree 81/08, 2008) states that the evaluation of risks must include all risks related to the health and safety of workers. In particular, repeated movements and efforts are considered causes of risks for health, and therefore the employer is obliged to analyse this type of risk.

Moreover, a voluntary technical norm has recently been adopted by ISO, which is considered the reference for operating evaluations of this kind. This norm is *ISO 11228-3; Ergonomics – Manual handling – Handling of low loads at high frequency* (ISO 11228-3, 2007) and it is directly reported by Legislative Decree 81/08; here we can find the suggested (favourite) method: OCRA (OCcupational Repetitive Actions). The technical standard ISO 11228-3 is also the reference in the processes of risk assessment of repeated movements and efforts of the upper limbs for the Lombardy region (one of the twenty administrative regions of Italy, in the northwest of the country; specifically, the major contributor to Italian GDP, summing 21.6% of the national GDP in 2015 – see Banca d'Italia, 2016 –, mainly due to a flourishing manufacturing industry).

The OCRA method is now considered not only the Italian standard, but also the European and international one, in addition to a list of well-known available methods (in the following, some examples are reported): ACGIH HAL TLV (American Conference of Governmental Industrial Hygienists , 2004), Checklist OSHA (Schneider, 1995), OREGE (Hervet and Vallerey, 2001), RULA (McAtamney and Corlett, 1993), Job Strain Index (Moore and Garg, 1995), and so on. The purpose of this paper is to highlight the limits of the existing methods, including OCRA, and to devise a new method that will eventually bridge the gaps.

2. Purpose

Currently, safety experts have to appraise the risk of UL-WMSDs using the methods available in order to provide risk indexes that indicate the level of criticality of a particular job or task. Nonetheless, we live in a time when companies need to innovate constantly and cannot afford to rely on a static and antiquated product lines or workstations. We are therefore experiencing a continuous proliferation of new technologies and products. The heart of innovation in industry lies in the stages of new product and process design. As far as the most renowned industrial engineering handbooks (e.g., Salvendy, 2001 as for the workstations), new product development handbooks (e.g., Loch and Kavadias, 2008 as for the new product design), and professional experience of the authors are concerned, the design of a new workstation comes after the design of a new product, mainly in terms of operational performance, whilst whatever has to do with UL-WMSD Risk Assessment is typically performed separately, once the workstation itself has been fully set. Each of the two aspects follows its own path without the ability to interface with each other. However, in principle there is no reason for thinking that design (of the product and of the workstation for the sake of operational performance) and safety cannot be immediately considered in a merged way. There is no doubt that intervening later in the causes of risk of UL-WMSDs (that is, once a workstation is fully set and running) costs much more than intervening in the design phase (that is, no need of buying new machines/equipment and/or paying for the construction and set up works in order to deal with unacceptable risk level). This is not to say that existing methods cannot help in some way in the design. This possibility is partly evident in the method of the OCRA Index, but this only provides useful data in relation to redesigning the workplace, particularly when the product to produce/assemble (and the associated tasks) does not change significantly. Still, it has to do with redesigning, not designing. We must also wonder whether the risk sources are connected exclusively to the peculiarities of the workplace and to the process: it is logical to expect that the design features of the product that we are going to produce/assemble may influence the risk associated with the job. Let us consider, for example, a product that is difficult to assemble,

Please cite this article in press as: Micheli, G.J.L., Marzorati, L.M., Beyond OCRA: Predictive UL-WMSD risk assessment for safe assembly design, International Journal of Industrial Ergonomics (2017), http://dx.doi.org/10.1016/j.ergon.2017.07.005