Assessment tools analysis of work-related musculoskeletal disorders: strengths and limitations

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Abstract. Musculoskeletal disorders are one of the most common occupational diseases, affecting millions of workers in the European Union and costing employers billions of euros. Researching the relationships and possibilities of optimal mutual adaptation, under given conditions, both of human to his work and of work to humans, in order to increase the technical-economic efficiency, to optimize the conditions of satisfaction, motivation and work results, while maintaining the worker's state of health also involves, as a basic stage, the assessment of the risks of osteo-muscular-articular overload. Starting from a statistical synthesis on the incidence of MSD and the characteristic types of demands, the paper systematizes in a unitary vision the categories of methods, techniques and tools available for recording and evaluating the factors of physical and postural stress of workers. The pointed description of three of the most commonly applied ergonomic risk assessment tools, aimed at developing a synthesis of Strengths-Weaknesses type, which highlights the advantages of methods in counterbalance with their limitations, providing a first basis for selection in order to apply them in the practice of companies that are aware that investing in safety means investing in profit and not losing financial resources and implicitly human, material ones.

1 Introduction

Although, in principle, risk assessment is a powerful and effective tool, if not used with care and discernment, the results obtained can be completely incorrect, leading to erroneous decisions, practically inapplicable [1-5]. Musculoskeletal disorders (MSDs) are one of the most common occupational health problems. They affect millions of workers across Europe and cost billions of euros for employers [6]. Manual handling, frequent bending and twisting, repetition of movements, hard physical work and vibrations are the main causes of

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MSDs [7]. Combating MSDs contributes to improving the lives of workers, but is also economically justified [8].

MSDs reduces the company's profitability and adds to the government's social costs [9]. But these health conditions also greatly reduce the employability and work capacity of those affected. According to EU-OSHA in 2020 in Europe the main part of the costs of occupational diseases is due to cancer, followed by musculoskeletal disorders (MSDs). Figure 1 illustrates the main occupational diseases and DALY (disability-adjusted life years) per 100,000 workers, in the European Union and in Romania in 2017 [10].

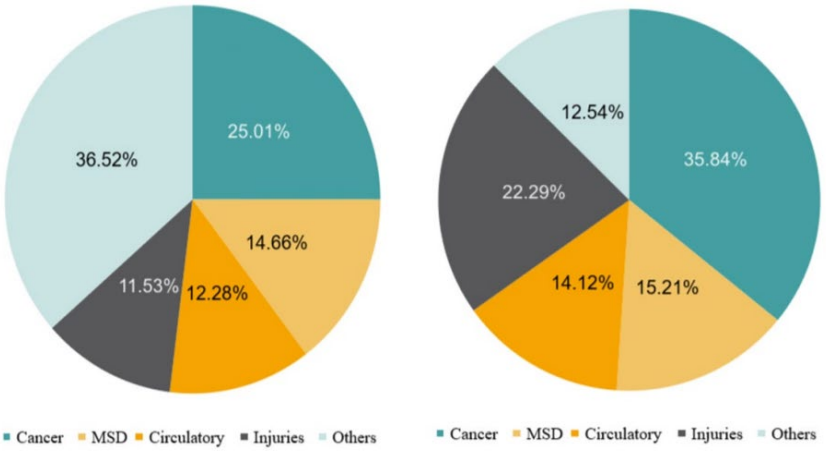

Fig. 1. The main occupational diseases and DALY in the last 3 years: European Union (left) and Romania (right) [10]

Musculoskeletal disorders of professional origin are disorders of body structure, such as muscles, joints, tendons, ligaments, nerves, bones and the local circulatory system, which are caused or aggravated mainly by professional activity and the characteristics of the work environment in which it takes place.

The causes of MSDs are multifactorial and there are numerous physical and mechanical risk factors, organizational and psychosocial factors, as well as individual and personal factors can contribute to the genesis of MSDs. Workers are generally exposed to several factors at the same time, and the interaction of these effects is often unknown. [11] [12]. Regarding physical risk factors, studies have found reasonable evidence for an association between different types of MSDs and the following physical risk factors. [13-14]:

- ***Frequency and repetition of movement*** - includes rapid or prolonged movements of the upper limb. The work is repetitive when it requires the use of the same muscle groups repeatedly during the working day or the movements are performed frequently for long periods. Such repetition may not allow enough time for recovery and may cause muscle fatigue, which may lead to an increased risk of upper limb disorders.
- ***Applied force*** - includes handling heavy objects, fast movements when performing a task. The level of force generated by the muscles is affected by a number of factors, including workstations, the size of the objects handled and the speed of movement. The use of excessive force can lead to fatigue and, over a period of time, to upper limb disorders.
- ***Awkward postures*** - include awkward and prolonged postures of the head, neck, back, arms and wrists. Some jobs may require an employee to take on a variety of awkward positions, including fixed or restricted body positions,

which cause significant biomechanical stress to the joints of the upper limbs and surrounding soft tissues. Such postures can restrict blood flow to muscles and tendons and cause muscle fatigue, leading to a lower chance of muscle recovery..

- ***Duration of exposure*** - is the length of time for which the task is performed. It can refer to the number of hours in which the task is performed without a break or in a typical daily change. It may also include the number of working days for which the task is performed (for example, 4 hours per day, 5 days per week).

Data from the European Working Conditions Survey (EWCS) show that the incidence of MSDs is associated with working in tiring or painful positions, carrying or moving heavy loads, and repeated hand or arm movements. This applies to all three types of MSDs that are distinguished in the EWCS (back, upper limbs and lower limbs). Other MSDs may also be associated with other physical risk factors, such as vibration from hand tools and machinery and low temperature.

A comparison of EWCS data from 2005, 2010 and 2015 shows a slight decrease in exposure for most of these risk factors. Despite this positive trend, the data show that European workers remain exposed to more physical hazards associated with MSDs. For example, one third of workers (32%) carry heavy loads for at least a quarter of their working time, while almost one in five (20%) are exposed to vibration. As Figure 2 shows 40% of all workers work in tiring or painful positions for at least a quarter of the time, and 62% are exposed to repetitive hand or arm movements [15].

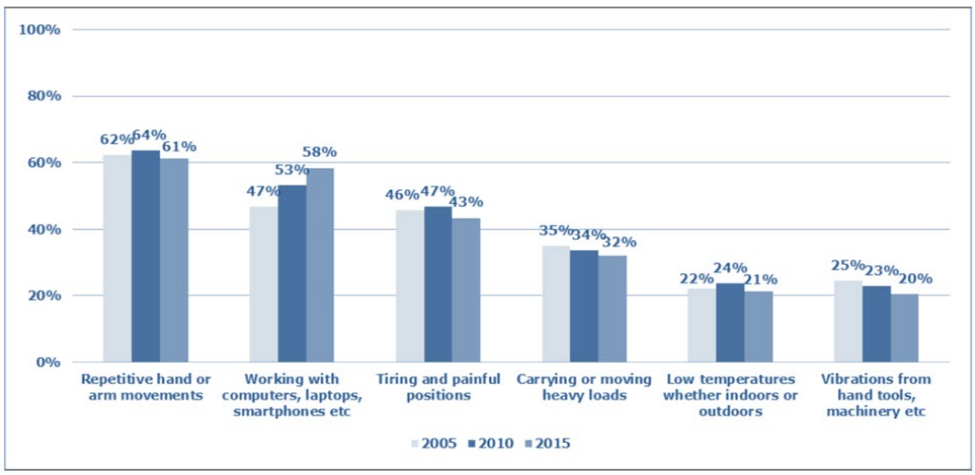

Fig. 2. Percentage of workers who report being exposed to various physical risk factors at work at least a quarter of the time, EU-28, 2005, 2010 and 2015 [15]

2 Materials and methods

Numerous methods are available to identify and assess physical load factors, from interviews and surveys, field measurements and video analysis to laboratory measurements and simulations.

Instruments such as MORT (Management Oversight Risk Tree) -1975, Laboratory of Ergonomics and Sociology of Work - LEST of CNRS, ERGOS, Safety Diagnosis Questionnaire, DSF (Diagnosis Safety Form) -1974, DCT (Diagnosis of Working Conditions) - 1984, the job profile method (Renault-RNUR) and many others approach

postural demands from an ergonomic perspective, i.e. from the point of view of the "*grouping of biological-medical, psychological-social and technical sciences, in order to research relationships and possibilities of optimal mutual adaptation , in given conditions, both of the man at his work and of the work at man, in order to increase the technical-economic efficiency, to optimize the conditions of satisfaction, motivation and work results, simultaneously with maintaining health and promoting personality development* " [8].

However, these methods differ, inter alia, in the accuracy of the recording and assessment of workloads [16].

Assessment often targets the risk to a particular region of the body (e.g. spine). The aim is to classify physical work tasks and to provide an overview of the main methods for recording and evaluating them.

The succession of stages whose application is necessary in an adapted manner, depending on the whole set of particularities specific to the investigated job / workplace - and implicitly the typologies of tools that can be used - is shown in a schematic manner in figure 3.

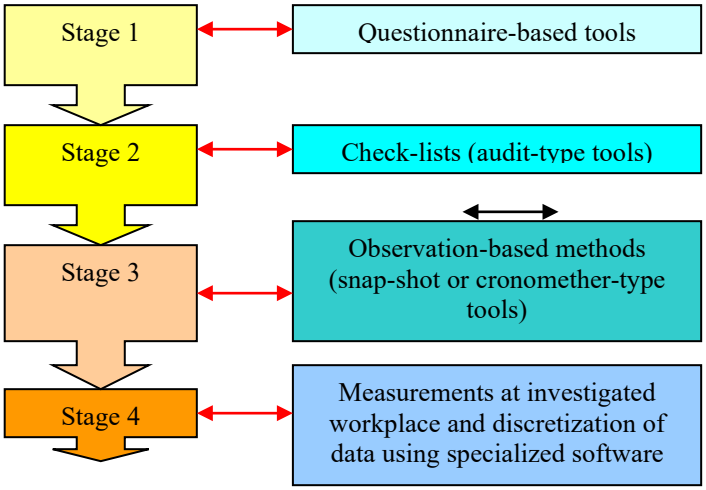

Fig. 3. The succession of the methodological stages applicable for the evaluation of the risks of musculoskeletal disorders in the occupational environment

Stage 1 represents the questionnaires and data reported by the workers. In this category, workers must estimate the daily frequency of manual handling of the masses. Various MSDs assessment tools often use data reported by workers to assess exposure. These questionnaires do not always reflect the real situation, as workers' ability to estimate daily exposure is limited, and workers already suffering from MSDs tend to overestimate their exposure.

In ***stage 2***, checklists are used to identify the frequency and task handled at work. Checklists normally contain limit values for assessing a specific task.

If the workload is more complex such as lifting, supporting, carrying, pushing, sliding or pulling the manipulated masses, it is advisable to use observation-based methods (***stage3***) for a more accurate assessment of risk factors. Examples of detection methods in this category are the Key Indicators Method (KIM), which addresses lifting and transporting, pulling and pushing masses, the RULA method for assessing limbs and upper body [17-19], and the REBA method for assessment of the whole organism [20].

Observation methods are subject to the usual limitations and the disadvantage of these methods is that they only classify workload categories and often do not adequately reflect the complexity of work processes, especially three-dimensional movements such as torsion and lateral flexion of the back and proper assessment of the workload pattern and resting time.

Therefore, some applications require measurements of stresses to be performed directly at the workplace (***stage 4***). A series of measurement systems have been developed for recording and analyzing body posture and movements in the work process. Most of them are specially designed for recording body parts movements and computer-assisted recording and long-term analysis of musculoskeletal loads. They allow continuous recording and analysis of physical stress factors directly at work. Depending on the application, the measurement methods allow an evaluation based on biomechanical, muscular, cardiopulmonary and psychophysical criteria [21-22].

2.1 Key Indicators Method

The Key Indicators Method (KIM) was designed to assess the risks of observation in the case of manual mass handling. The objectives of the method are:

- description of the essential requirements regarding the task and working conditions;
- quantification of the level of demand;
- objective risk assessment - calculation of the level of risk;
- indication of intervention points (redesign and / or medical care).

Different features of the stress related to manual mass handling are taken into account:

- biomechanical pressure on bones, joints and muscles resulting from forces of action and forced positions;
- muscle fatigue resulting from the generation of intensive, frequent or persistent force;
- cardiovascular system stress due to high physical load;
- disabilities caused by the characteristics of the load handled (bulky, slippery, very large);
- risk of injury caused by the characteristics of the load (very heavy, sharp, mobile);
- risk of injury caused by the characteristics of the work environment (uneven or slippery ground, reduced movement space for workers, obstacles, insufficient lighting).

Two different worksheets are available:

- Activities that involve *lifting, supporting, carrying* and,
- Activities involving *pulling, sliding and pushing*.

The assessment is practically performed for manual handling tasks and must be reported to a working day. If the load and / or positions change in an individual activity, average values must be found. If several manual handling tasks with substantially different manipulations occur in the general activity, they must be estimated and documented separately.

The next 3 steps are required in the evaluation:

- Determination of time indexes;
- Determination of indexes for key indicators (mass, posture and working conditions index);
- The evaluation itself.

2.2 *Rapid Upper Limb Assessment*

Rapid Upper Limb Assessment (RULA) was developed to assess workers' exposure to ergonomic risk factors associated with upper extremity MSDs. The RULA ergonomic assessment tool takes into account the requirements for biomechanical and postural loading of loads on the neck, torso and upper extremities.

RULA uses a systematic process and consists of a worksheet to assess body posture, frequency and strength required to perform the task. Based on the observation, scores are assigned to each part of the body (arm and wrist, neck and torso) and a single score is calculated that represents the level of risk of MSDs [19].

At the workplace or the analyzed activity, the data regarding the exposed personnel, the manipulated masses, the work rhythm, the work environment, the jobs for each type of activity are collected. For each work task, the basic activities are identified, for each assessing the risks of posture and manual manipulation of the masses, assigning a score for each part of the body exposed to the demands.

Depending on the working positions, the scores for the arms, forearms and palms are assigned, with the corresponding adjustments, separately for each of the two upper limbs to find out the scores corresponding to the members' positions. The neck, torso and leg positions are also scored, with the necessary adjustments obtaining the score for the whole body..

2.3 *Rapid Entire Body Assessment*

The REBA method has been proposed for assessing musculoskeletal risks to postural exposure as well as that related to manual manipulation of masses. At the workplace, the data related to the exposed personnel, the manipulated masses, the work rhythm, the work environment, the work stations for each type of activity are collected, meaning that it is recommended to take photos in order to establish the postures objectively.

For each work task, the basic activities are identified, for each assessing the risks of posture and manual manipulation of the masses, assigning a score for each part of the body exposed to the demands. Depending on the workstations, the scores are assigned for the trunk, neck, legs, with the necessary adjustments, in order to find out the score corresponding to the posture of the whole body. The positions for the arms, forearms and palms are also scored, with the appropriate adjustments, for the score corresponding to the upper limbs [20].

The REBA method is suitable for the evaluation of the whole body and is optimal for both static and dynamic works.

3 Results

Considering the quasi-incipient stage in which the economic analysis of the costs associated with the unwanted events occurred in the occupational environment is in Romania, the comparative study carried out on the three investigated methods and techniques aimed at investigating their practical feasibility, in particular and specific socio-economic conditions.

Table 1 summarizes the results obtained, expressed in the form of a synthesis of type Strengths-Weaknesses, which highlights the advantages of methods in counterbalance with

their limitations, providing a first basis for selection for application in the practice of companies that are aware that investing in safety means investing in profit and not losing financial resources (and implicitly human, material, etc.)

Table 1. Results obtained: advantages and limitations of the investigated methods

<table>
<tr><th></th><th>Key Indicators Method</th><th>RULA method</th><th>REBA method</th></tr>
<tr><td rowspan="4">STRENGTHS</td><td rowspan="4">It is an easy method to apply, no special training in ergonomics is required, only a good knowledge of the workload to be assessed and basic knowledge regarding occupational safety and health (OSH).</td><td>Scores indicate the level of intervention required to reduce the MSDs risk</td><td>Computerized data recording.</td></tr>
<tr><td>Complements other ergonomic methods.
It is easy to apply and does not require special equipment.
It is fast and cost effective.</td><td rowspan="3">Neutral posture as positions with some intervals of angular deviations of the associated joints and by classifying the positions of the legs in four classes</td></tr>
<tr><td>It is useful for evaluating workers with sedentary work (computer jobs, in the garment industry, etc.)</td></tr>
<tr><td>The neutral position of the wrist, neck and torso with 0 ° angle of movement of the corresponding joint and the positions of the changeable legs are classified into two classes: balanced and unbalanced</td></tr>
<tr><td rowspan="4">WEAKNESSES</td><td rowspan="4">During the assessment of risks at the level of observation, there is a possibility of assessment error or misinterpretation. This may result from insufficient knowledge of the task to be assessed, from a subjective interpretation, from incorrect data or calculation errors.</td><td>The assessment of the right and left upper limbs is not done separately.</td><td>There is no difference between the right upper limb and the left one.</td></tr>
<tr><td>Repetitive movements are not taken into account.</td><td>The user must decide which position to choose (more often they are repetitive positions, positions that require considerable effort or cause discomfort)</td></tr>
<tr><td rowspan="2">It cannot be used when workers perform many different tasks (when it requires increased attention from the observer).</td><td>The most vicious position depends on the part of the body that is most exposed.</td></tr>
<tr><td>The time of completion of a certain task is not taken into account.</td></tr>
</table>

4 Conclusions

The aspects researched in this paper allow the formulation of the following conclusions, meant to guide the process of improving the way of carrying out the evaluation of the risks generating MSDs in our country:

1. Achieving risk assessment in an attempt to justify a decision already taken for other reasons, not involving a team in the assessment process or not including workers in the team, inefficient use, sometimes formal, of external consultants, not using the results obtained or not correlating hazards with control measures are just some of the specific errors that continue for more than 10 years to burden in Romania the quality of the results of a process that continues to be, unacceptably frequent, characterized by an impractical formalism.

2. While the basic purpose of risk assessment is always to prevent occupational hazards, achieving this goal is not always possible in practice. Where it is not possible to eliminate the risks, they must be reduced and the residual risk must be controlled. In the later stages and within a rigorous control program, the residual risks will be re-evaluated, analyzing the possibility of their elimination or further reduction, as a result of the evolution of scientific and technical knowledge. The assessment of occupational risks must always be verified when there is a change that could affect the perception of risks, when new materials or equipment are introduced or when the organization or working conditions change, including transfer to other workshops or decommissioning of the system.

3. In some cases, a single assessment that "covers" all the risks in a system, job or activity may be sufficient. In general, it is recommended to adopt different approaches depending on the purpose of the analysis and the information available in the preliminary analysis phase. When occupational risk assessment is considered necessary, the fastest and most effective way to know the real situation in a work system is to develop questionnaires that seek answers from employees who actually work at the jobs analyzed.

4. The KIM, REBA and RULA methods, which have been analyzed comparatively and critically, from the perspective of strengths and specific limitations, offer the opportunity to study in detail the risks of musculoskeletal disorders for workers frequently exposed to specific postural demands. Applied with discernment and taking into account the specificities of the jobs analyzed, they can be powerful tools to substantiate the decision on the allocation of resources to minimize the risks of unwanted events (accidents, incidents, occupational diseases-especially) induced by manual handling of the masses.

5. Given the major incidence of these types of health problems in the current occupational environment, we can conclude that there is a real and vast potential to improve the level of safety and health at work in Romania, especially if we consider the fact that the use of this category of risk analysis methods is not only sporadic and unsystematic, but is a "rara avis" in the "monotonous" landscape of risk assessment at the national level.

References

1. L.I., Cioca, R.I., Moraru , G.B., Băbuț, A Framework for Organizational Characteristic Assessment and their Influences on Safety and Health at Work, *Proceedings of the 15th International Scientific Conference „The Knowledge Based Organization”*, vol. **2**, section: Management, pp. 43-48, Land Forces Academy Sibiu, Romania (2009).
2. R.I. Moraru, G.B. Băbuț, Principles and guidelines regarding the risk management implementation: The new ISO 31000:2009 standard, *Quality - Access to Success Journal,* **11**, Issue 4, pp. 50-59, (2010).
3. R.I. Moraru, G.B. Băbuț, L.I. Cioca, Study of methane flow in caved goafs adjacent to longwall faces in Valea Jiului coal basin, *Proceedings of the 13th SGEM GeoConference on Science and Technologies in Geology, Exploration and Mining - SGEM 2013*, **I**, 731-738 (2013)
4. Moraru, R.I., Băbuț, G.B., *Research on methane emission mechanism and pattern in a longwall coal face at Livezeni colliery, Proc. of the 14th Int. Multidisciplinary Scientific Geoconference - SGEM 2014,* Volume III, pp. 497-504, Albena, Bulgaria, 17-26.06 (2014).

5. R.I. Moraru, G.B. Băbuț, L.I. Cioca, Drawbacks and traps in risk assessment: examples in Romania, *Proceedings of the 5th International Conference on Manufacturing Science and Educations - MSE 2011*, Volume 2, pp. 363-366, Sibiu, Romania (2011).
6. A. Gaureanu, A. Drăghici, H. Weinschrott, Increasing the quality of occupational safety and health implementations through awareness training for those involved in implementing the Safety Observation Report, *Quality - Access to Success*, Vol. **20**, pag. 141-146, supplement: **1**/(2019).
7. G.B. Băbuț, R.I., Moraru, Occupational risk assessment framework in Romania: an institutional perspective*, Proceedings of the 16th International Multidisciplinary Scientific GeoConference (SGEM 2016): Science and Technologies in Geology, Exploration and Mining*, Volume 2, pp. 635-642, Albena, Bulgaria, 30.06-06.07, (2016).
8. R.I. Moraru, *Occupational Health and Safety: University Handbook (in Romanian),* Universitas Publishng House, Petroşani, (2013).
9. R.I. Moraru, G.B. Băbuț, M. Popescu-Stelea, Prerequisites for safety diagnostic and risk analysis integration in complex industrial facilities, *Quality - Access to Success*, **17** (151), 92-99, (2016).
10. EU Science Hub. *EU burden from non-communicable diseases and key risk factors*, 2020, Accessed on 4 November 2020 at https://ec.europa.eu/jrc/en/health-knowledge-gateway/societal-impacts/burden, (2020).
11. J.K. Park and, S.H. Jang. (2010). Association between Upper Extremity Musculoskeletal Disorders and Psychosocial Factors at Work: A Review on the Job DCS Model's Perspective. *Safety and Health at Work*, 1(1), 37–42.
12. P. Drinkaus, D.S. Bloswick., R. Sesek, C. Mann, and T. Bernard. Job level risk assessment using task level strain index scores: a pilot study. *International Journal of Occupational Safety and Ergonomics* : *JOSE,* 11(2), 141–152 (2005).
13. M.N.A. Rahman, F.A. Aziz, and R.M. Yusuff. Survey of body part symptoms among workers in a car tyre service centre. *Journal of Human Ergology*, 39(1), 53–56, (2010).
14. B. P. Bernard. *Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.* Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-141. (1997)
15. Crawford, J., Graveling, R, Davis, A, Giagloglou, E., Fernandes, M., Markowska., Jones, M, Fries-Tersch, E., *Work-related musculoskeletal disorders: from research to practice. What can be learnt?* European Risk Observatory Report, EU-OSHA, 2020, Accessed on 10 January 2021 at https://osha.europa.eu/ro/publications/work-related-musculoskeletal-disorders-research-practice-what-can-be-learnt/view, (2020).
16. L. Punnett, D. H. Wegman. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of Electromyography and Kinesiology*, 14(1), 13-23 (2004).
17. A. Garg, J. M. Kapellusch. Job analysis techniques for distal upper extremity disorders. *Reviews of Human Factors and Ergonomics*, 7(1), 149-196 (2011).
18. E. Occhipinti. OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics,* 41(9), 1290-1311, (1998).
19. L. McAtamney, E.N. Corlett, Rapid Upper Limb Assessment (RULA), Applied Ergonomics 24(2), 91-99, (1993).
20. S. Hignett, S, L. Mc Atamney, Rapid Entire Body Assessment (REBA), Applied Ergonomics 31:201-205, (2000).
21. M. E. Chiasson, D. Imbeau, K. Aubry, A. Delisle. Comparing the results of eight methods used to evaluate risk factors associated with musculoskeletal disorders. *International Journal of Industrial Ergonomics*, 42(5), 478-488. (2012).
22. B. Cirjaliu, A. Mocan, M. E. Boatca, A. Draghici, A propose approach for continuous improvement using ergonomics and quality management knowledge and methodologies. *Quality Access to Success*, 20(S1), 135 (2019).