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MAPPING OF ERGONOMIC ASSESSMENT TOOLS

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ABSTRACT

Ergonomists use in their daily routine instruments, which these professionals call analysis tools. Each one of them has a scientific basis and an intended use. The objective of this study was to perform a mapping of the ergonomics tools most often cited in the scientific literature, with the objective of detailing and differentiating the main characteristics. After performing an RBS with the key words that indicate tool use and ergonomic risk assessment, 82 tools were mapped, from which the authors of this article selected the 10 most cited and performed an investigation of their main characteristics and functionalities. We then concluded that each of these tools has its intended use, and the overlapping of tools indicates a lack of effectiveness. Further, we still observed the great influence of analysts (human-dependence) over non-technology tools, thus the use of technology is not yet fully applied to the work reality in a broad way.

KEYWORDS: Ergonomics tools, Working Posture Analysis, Musculoskeletal Disorders, Risk Assessment.

1. INTRODUCTION

Currently the evaluation of the interaction between human beings and work is one of the main tasks of ergonomists. By understanding that in ergonomics the posture and movements of workers are the main information determining the risk of development of musculoskeletal injuries, these professionals use tools to measure human exposure to working conditions (Vieira and Kumar, 2004). As observed in the annual yearbook Health Brazil 2018, published by the Ministry of Health, these interactions when not favourable to humans, can cause various disorders, pointing out that between the years 2007 and 2016, 67,599 cases of Work-Related Musculoskeletal Disorders (WMSD) were registered. In addition, it states that there was an important growth from 3,212 cases in 2007 to 9,122 in 2016 (Brasil, 2019).

It is observed that companies, including complying with the legislation, hire ergonomics professionals to perform the analysis of workstations to measure the existing risks. And that these ergonomic analyses of work (EAW) are basically evaluations of the task, posture, movements, and the physical-cognitive demands of the worker (Iida, 2005; Mascle and Vidal, 2011). The objective of the present study was to perform a mapping of the ergonomic tools most often cited in the scientific literature, as well as to detail and differentiate the main characteristics of each of the tools.

2. BACKGROUND

Ergonomics probably began to exist when the prehistoric man chose some stone that best suited the shape and movements of his hand, to use it as a weapon, to hunt, cut and crush (Iida, 2005). According to Couto (1995 and 1998) ergonomics evolved from man's efforts to adapt tools, weapons and utensils to their needs and characteristics, being initially documented the term ergonomics in Poland in 1857 published by W. Jastrzebowski, but only in the next century the concept gained strength. Therefore, the current concept of ergonomics appeared after the 2nd World War as a result of the interdisciplinary work performed by professionals such as engineers, physiologists and psychologists who were necessary for the solutions used during the war to adapt equipments to the users.

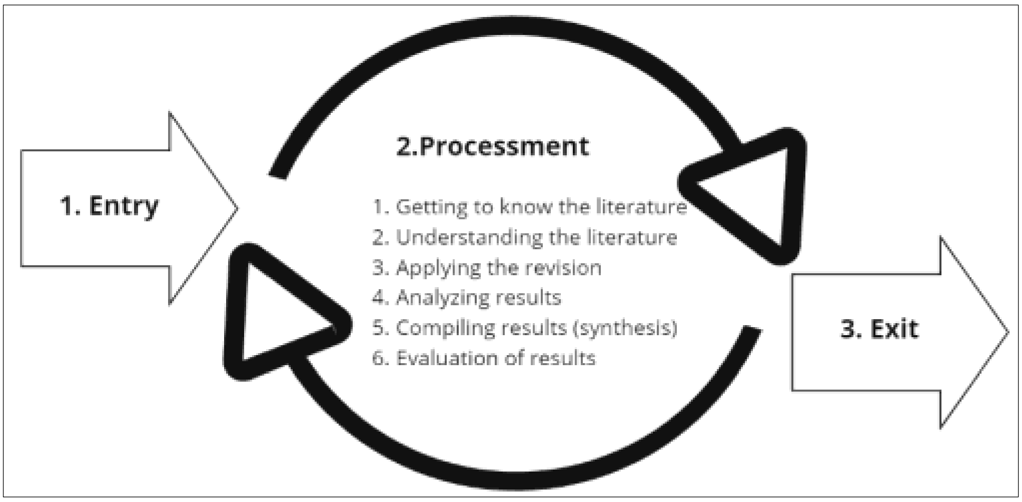
Wisner (1987) defined ergonomics “as a set of scientific knowledge related to man necessary to engineer tools, machines and devices that can be used with the maximum comfort, safety and effectiveness”.

Iida (2005) defined ergonomics in the broadest aspect of work as the adaptation of work to man, which includes all situations in which productive activity occurs, considering the physical, cognitive, and organizational aspects. This same author expands the debate citing the concept of the Ergonomics Society of England: "Ergonomics is the study of the relationship between man and his work, equipment, environment, and particularly, the application of knowledge of anatomy, physiology, and psychology in solving problems that arise from this relationship".

This article presents data that were collected on a research positioning within physical ergonomics studies, which is concerned with the characteristics of human anatomy, anthropometry, physiology, and biomechanics, related to physical activity. Relevant topics include posture at work, material handling, repetitive motion, and work-related musculoskeletal disorders, using tools that measure the expositions that workers are subjected to. (Iida,2005).

To conduct the mapping, the authors chose the SBR (Systematic Bibliographic Review) methodology cited by Levy and Ellis (2006) and adapted by Conforto, Amaral and Silva (2011), which is a process of collecting, knowing, understanding, analysing, synthesising, and evaluating a set of scientific articles with the purpose of creating a theoretical-scientific background (state of the art) on a given topic as described in figure 1:

Figure 1 – Phases of the systematic literature review



Source: Conforto, Amaral and Silva (2011).

3. METHODS

We developed this article by initially carrying out a literature review, followed by an SBR, by mapping and describing the tools. Then we tabulated the data and described each of the 10 most cited tools including the characteristics, strengths, and weaknesses of the mapped tools.

The SBR was performed using the search engine of the site "periódicos.capes" (22 to 28/06/2020). By using the keyword filter "ergonomics" the system presented 4,385 articles, and with further keywords (listed in Table 1) the following applied selection criteria peer-reviewed articles, published in English, in journals of all the bases of the site, and published in the last 5 years (2015-2020), the system delivered 610 articles:

Table 1. List of strings and number of articles located.

Strings	n
Ergonomics + working posture	25
Ergonomics + Musculoskeletal disorders	271
Ergonomics + Working posture analysis	9
Ergonomics + Risk assessment methods	27
Ergonomics + Risk assessment	137
working posture + Musculoskeletal disorders	12
working posture + Working posture analysis	30
working posture + Risk assessment methods	2
working posture + Risk assessment	11
Musculoskeletal disorders + Working posture analysis	5
Musculoskeletal disorders + Risk assessment methods	12
Musculoskeletal disorders + Risk assessment	60
Total	**610**

Source: Authors (2021)

In the following steps the tools used in each article were identified. The reading of the articles revealed that most of the articles do not mention the used tools neither in the title, nor in the key words. A small part of the articles mentions this information in the abstract, thus for identification of the applied tools it was necessary to read the methodology of each article. When performing the selection of the articles according to the used tools, 82 tools distributed in 220 articles were listed.

After this step the citation frequency of each tool was counted, and the 10 most cited tools were selected, which corresponded to 72% of the citations indicating the following tools showed in Table 2.

The selected tools of this process were categorized and analyzed by the following aspects. The tools selected in this process were then categorised and analysed in terms of the following aspects: Evaluation methodology; Focused risks; Applicable tasks; Related precision; Advantages; Limitations; Field study versus laboratory; Type of tool; Costs; Time/work.

The results are shown and discussed in the Chapter 4.

Table 2. Relation of the detected main tools.

	Evaluation tool	n	%
1	NORDIC	45	14%
2	RULA	45	14%
3	REBA	34	10%
4	OWAS	26	8%
5	EMG	23	7%
6	Kinematics	17	5%
7	OCRA	14	4%
8	NIOSH	13	4%
9	IMU	11	3%
10	Strain Index	8	2%
	Total	**236**	**72%**

Source: Authors.

4. Results and Analysis

In Table 3, the authors present the results found, listed by the year of publication. It can be seen that there is a concentration of publications in the 1990s, due to a concentration of studies seeking to develop a tool to study and analyse repetitive force and musculoskeletal disorders in this period.

Table 3. Relation of the detected main tools and their respective years of publication.

Tool	Year of publication	Reference
EMG	1968	FAULKNER, 1968
OWAS	1977	KARHU *et al.* , 1977
NIOSH	1981	NIOSH, 1981
NORDIC	1987	KUORINKA *et al.* , 1987
RULA	1993	MCATAMNEY and CORLETT, 1993
Kinematics	1993	ROEBUCK, 1993
Strain Index	1995	MOORE and GARG, 1995
OCRA	1998	COLOMBINI, 1998
REBA	2000	HIGNETT and MCATAMNEY, 2000
IMU	2009	BREEN *et al.,* 2009

Source: Authors. (2020)

Based on the data presented in Table 3, the authors mapped the main characteristics and the use of the tools in the publications found:

4.1. Mapping of the Tools

EMG – Surface Electromiography

The first records found during the present survey, date back to 1968 with the research "Electromyography and the study of work by Faulkner at the National Meeting of the American Institute of Industrial Engineering. Already in 1973, Khalil brings a new technique for the evaluation of industrial designs, based on electromyographic records of the muscles involved in the execution of the intended task. A hybrid computer circuit quantifies the total muscular effort expended in the execution of the industrial task and the design that optimises this measurement is selected. The methodology has proven being effective in evaluating the effort associated with static and dynamic tasks, thus demonstrating that it can be applied in a multitude of situations.

In occupational health, the upper trapezius (UT) muscle is usually investigated by surface EMG because it is a superficial muscle, and its activity is influenced by neck or shoulder pain. The relationship between EMG and strength is strongly dependent on muscle control by the central nervous system. This can change depending on muscle pain or fatigue (Troiano et al., 2008).

Muscle fatigue consists of myoelectric and mechanical phenomena, the former preceding the latter. The myoelectric manifestation of fatigue includes both "peripheral" and "central" muscle adaptations. Interesting indications have been obtained from EMG studies on the distribution of muscle fibre type, prediction of endurance time (ET) and pathological conditions. To increase the reliability of the information extracted from surface EMG, detection systems have been recently applied (Troiano et al., 2008).

Surface EMG sensors are best suited for measuring muscle forces in the workplace without interfering with a worker's normal movement patterns. EMG monitoring equipment provides data focused on just one risk factor, but with a high level of detail. Furthermore, several metrics (mean, peaks, percentiles, cumulative exposure, rate of change) can be investigated by means of EMG, with the disadvantage of being an expensive solution compared to traditional observation methods. EMG can be used as a tool for non-standard assessment. Considering the EMG assessment in the context of standard scoring methods, it has been used to complement a modified version of the RULA scoring system and as an alternative to visual inspection according to the BORG scale, since it is shown that the two assessments are strongly correlated (Peppoloni et al., 2016).

OWAS - (Ovako Working Posture Analysing System)

OWAS was developed in Finland between 1974 and 1978 by the researchers Karhu, Kansi and Kuorink for being used by working engineers as a part of daily routine or as a separate analytical tool. The method is based on work sampling (variable or constant interval sampling) and provides the frequency of time spent in each posture. The postures are classified, and their discomfort evaluated so that a systematic guide for corrective action can be constructed (Karhu et al., 1977).

To evaluate each posture from the point of view of discomfort caused and effect on health, a classification system was established for each posture using a schematic design. The employed four-point rating scale had the following extremes: "normal posture without discomfort and no health effect "and" extremely bad posture, short exposure leads to discomfort, possible harmful health effects". From the workers' ratings, an average rating was calculated for each posture and a ranking order was established (Karhu et al., 1977).

Based on pen and paper the observational OWAS method with a sampling interval, 25 seconds, is easy to use and allows a quick assessment. The OWAS method is based on a classification of different postures for the back (neutral, leaning forward, twisted, bent and twisted), arms (both arms below the shoulders, one arm above the shoulders, both arms above the shoulders), legs (sitting, standing with both legs extended, standing with one leg extended, standing with one knee bent, standing with both knees bent, kneeling, walking) and the force/load (less than 10 kg, between 10 and 20 kg, more than 20 kg) present during the task (Lasota, 2020).

The proposed framework is easy to understand as well as apply and can fully meet the expectations of professionals. Furthermore, to ensure a certain ergonomic quality in the design phase, digital human modelling, and methods such as OWAS or RULA can be used in the virtual environment (Lasota, 2020).

The OWAS method presents a high degree of generality and a low sensitivity in relation to the handling of loads, not taking into consideration aspects such as vibration and energy expenditure. It proposes the analysis of posture without considering the cervical region, wrists, and forearms, becoming unfeasible when the lying posture is assumed. For the analysis of posture, strength, and work phase, it is necessary to observe the samples of activities collected from filming and direct observations and make estimates of time during which forces are exerted and postures assumed. As well as the phases selected for analysis are those that the observer considers to be of greater relevance to the worker, giving the method a characteristic of subjectivity since different observers will consider different phases (Souza; Rodrigues, 2006).

NIOSH – National Institute of Safety Health

The National Institute for Occupational Safety and Health (NIOSH) first developed an equation in 1981 to help safety and health professionals for assessing lifting demands in the sagittal plane (Niosh, 1981). The lifting equation was widely used by health professionals because it provided an empirical method to calculate a weight limit for manual lifting. This limit has been proven being useful in identifying work that poses a risk to the musculoskeletal system. However, the equation from 1981 could only be applied to a limited number of lifting tasks, i.e. sagittal lifting tasks, thus the equation was revised and expanded in 1991 (Waters et al., 1993).

The 1991 lifting equation reflects new findings, provides methods to evaluate asymmetric lifting tasks, hand-coupled objects and offers new procedures to evaluate a wider range of work durations and lifting frequencies than the previous equation. The goal of both equations is to prevent or reduce the occurrence of weightlifting-related low back pain among workers. The added benefit of this equation is the potential to reduce other musculoskeletal disorders or injuries associated with some lifting tasks, such as shoulder or arm pain. Three criteria (biomechanical, physiological and psychophysical) were used to define the components of the original and revised lifting equation (Waters et al., 1993).

The survey equation is a specialised risk assessment tool. As with any specialised tool, its application is limited to the conditions for which it is designed. Specifically, the lifting equation is designed to meet selected lifting-related criteria covering biomechanics, work physiology and psychophysical data. To the extent that a given lifting task accurately reflects these conditions and criteria, this lifting equation can be applied appropriately (Waters et al., 1993).

Limitations: The equation assumes that manual handling activities other than lifting are minimal and do not require significant energy expenditure, especially when repetitive lifting tasks are performed. It does not include task factors to account for unforeseen conditions such as unexpected heavy loads, slips or falls. It is not designed to evaluate tasks involving one-handed lifting, seated or kneeling lifting, lifting in a restricted work space, lifting people, lifting extremely hot, cold or contaminated objects, barrel wheel lifting, digging or high-speed lifting. It assumes that lifting and lowering tasks have the same level of risk (Waters et al., 1993).

In the revised version, the NIOSH equation presents the concept of the Recommended Weight Limit (RWL). Two other task variables, trunk asymmetry and manual coupling, have been introduced in the revised equation, in addition to horizontal and vertical location, travel distance, lifting frequency and duration of lifting work. Establishes a safety level and load limit in handling (Fox et al., 2019).

Nordic Questionnaire

Developed in 1987, this tool uses standardised questionnaires for the analysis of musculoskeletal symptoms. The questionnaires consist of structured, forced, binary or multiple choice variants and can be used as self-applied questionnaires or in interviews. There are two types of questionnaires: a general questionnaire and a specific questionnaire focusing on the lower back and neck/shoulder region. The purpose of the general questionnaire is a simple survey, while the specific ones allow a more in-depth analysis. The two main aims of the questionnaires are to serve as tools in the screening of musculoskeletal disorders in ergonomic context and in occupational health services. The specific questionnaires focus on the anatomical areas in which musculoskeletal symptoms are most common, these questionnaires investigate further the analysis of the respective symptoms and contain questions about the duration of symptoms over time (whole life, last 12 months and previous 7 days) (Kuorinka et al., 1987).

Advantages: Questionnaires can provide means to measure the outcome of epidemiological studies on musculoskeletal disorders; tracking musculoskeletal disorders can serve as a diagnostic tool to analyse the work environment, the workstation and the design of the tool; the occupational health service can use the questionnaire for multiple purposes: for diagnosing attrition at work, for monitoring the effects of improvements in the work environment, and so on (Kuorinka et al., 1987).

Disadvantages: The general limitations of questionnaire techniques also apply to these standardised questionnaires. The experience of the person completing the questionnaire may affect the results. Recent and more severe musculoskeletal disorders tend to be remembered more than older and less severe ones. The environment and the situation of filling in at the time of questioning may also affect the results. From the epidemiological point of view, it is evident that this type of questionnaire is more applicable for cross-sectional studies with all the concomitant limitations (Kuorinka et al., 1987).

The "Standardised Nordic Questionnaire" is an internationally respected instrument designed to standardise studies evaluating musculoskeletal complaints, being validated for application in Brazil, easily to understand and quickly to apply, thus offering substantial reliability (Barros; Alexandre, 2003).

RULA – Rapid Upper Limb Assessment

The RULA tool was developed in 1993 by McAtamney and Corlett. Its purpose is to find out whether workers are exposed to risk factors in the upper extremities during their work performance. The method evaluates three factors: the posture of the different areas of the body, the load or force exerted and the muscular activity (static posture or repetitive movements) (Gómez-Galán et al., 2020).

Part of the development took place in the garment industry, where assessment was carried out on operators performing tasks including standing on a cutting block, machining using one of a variety of sewing machines, shearing, inspection and packing operations. RULA was also developed by assessing the postures adopted, forces required and muscle actions of operators working on a variety of manufacturing tasks where risk factors associated with upper limb disorders were present (Mcatamney; Corlett, 1993).

It uses body posture diagrams and three scoring tables to provide risk factor exposure assessment. The risk factors under investigation are external load factors, being the following: number of movements; static muscular work; strength; work postures determined by equipment and furniture; time worked without interruption. Remembering that many other risk factors are associated with upper limb disorders, among them, individual factors, work, environmental factors and psychosocial variables (Mcatamney; Corlett, 1993).

Some advantages of the RULA method include being a reliable method for use on repetitive tasks, especially on upper limbs; applicable to workers in very different areas; the assessor does not need experience to apply it during the observation phase; it is a simple method to use and can be applied with the help of software (Gómez-Galán et al., 2020).

Gómez-Galán et al. (2020), brought a review with 226 articles referring to the application of the RULA method and articles were found in the most different areas of work, being common in administrative sectors and with daily use of the computer, but also in industry, in diverse sectors, where the method was effective in bringing the results of the musculoskeletal disorders found. Furthermore, the study shows in 34 countries where the RULA method was used, from which Brazil being in 6th place with the highest number of publications.

Cinematics

Motion capture techniques are commonly used in motion and animation analysis, as in rehabilitation, sports science, or ergonomic studies. In all cases, objective criteria are needed to access the movement of the patient, athlete, or machine operator. In the field of ergonomics, animation is for building digital human models, which is very useful to visualize and evaluate human-machine interactions, like the one between driver and car. In ergonomics not only visualization is needed, but also a scientific validation of the whole capture process (Monnier, 2004)

Roebuck (1993) discussed the existence of various methods of indirect collection through photography or videos. For anthropometric studies with photographs highlights the importance of care regarding the positioning and positioning of the camera.

The use of observational methods, either optical or magnetic in addition to wearable inertial sensors, to capture the motion of workers encounter difficulties when applied in real working conditions. They require the positioning of sensors or markers on the body and the calibration of the system and the manikin, which is not always possible in real working conditions, as sensors may be incompatible with safety constraints and may also be disturbed by the electromagnetic environment (Vignais et al., 2013; Battini et al., 2014; Plantanrd, 2016)

The advance of technology has allowed new studies to present solutions using RGB images and pose evaluation in an estimated manner using devices such as kinectic or artificial intelligence (Diego-Mas e Alcaide-Marzal, 2014; Mehrizi et al., 2017; Mehrizi et al., 2018).

The problems related to these two techniques arise precisely from the difficulty in building reliable models (mannequins), which changes the accuracy of the measurements. Typically, a skeleton model consists of 15-30 joints. Based on such skeletons, variables such as flexion / extension / torsion of body parts can be calculated (Plantanrd, 2016).

Strain Index

Strain Index (SI), was developed in 1995 by Moore and Garg. The objective of the proposed Si methodology, was to discriminate between jobs that perform and jobs that do not expose workers to musculoskeletal risk factors (task variables) that cause distal upper extremity disorders. The Strain Index attempts to answer the question "Is a specific job dangerous or safe?" in terms of the occurrence of distal upper limb morbidity among workers who do or have done the job (Moore and Garg, 1995).

The Strain Index is a semi-quantitative work analysis methodology that results in a numerical score (SI score) believed to correlate with the risk of developing distal upper extremity disorders. The index is based on multiplicative interactions between its task variables according to physiological, biomechanical and epidemiological principles. The Sl score represents the product of six multipliers that correspond to six task variables. These are (1) effort intensity, (2) effort duration, (3) efforts per minute, (4) hand / wrist posture, (5) work speed and (6) task duration per day. The authors determined that each task variable is classified according to five levels (Moore and Garg, 1995).

The physiological, biomechanical and epidemiological literature suggests that the strain aspects of a job are probably the most significant contributors to the occurrence of distal upper extremity disorders. The Strain Index is an exposure assessment tool that ergonomic professionals and teams can use to systematically assess the strain demands of a job to predict the increased risk of distal upper extremity disorder morbidity (Moore and Garg, 1995).

The application of the Strain Index involves data collection, assignment of rating values, determination of multipliers, calculation of the SI score and interpretation of the results. A job analyst or ergonomics team should collect data for all six task variables. Effort intensity, wrist posture and work speed are estimated using the verbal descriptors. Percent effort duration per cycle, effort per minute, and duration per day are based on measurements and counts. The data for each variable is then compared and given a rating from 1 to 5 (Moore and Garg, 1995).

A useful method to analyse tasks and predict risk potential, this score is used to classify the task into three categories: probably safe tasks (<3); tasks associated with the risk of upper limb distal extremity disorder (>5) and tasks that are probably dangerous (≥7) (Valentim et al., 2018).

Disadvantages: Applies only to the distal zone of the upper limbs (hand, wrist, forearm). A wide spectrum of disorders of the upper limbs can be predicted, including non-specific disorders. It allows the relative risk of a workstation to be calculated and not the risk of exposure to which a worker is subjected. The relationship between exposure and the values of the various multipliers is not based on an explicit mathematical relationship defined on the basis of physiological, biomechanical or clinical responses (Pavani; Quelhas, 2006).

Ocra - Occupational Repetitive Actions

The OCRA tool was published by Occhipinti and Colombini (1996). These researchers developed the work in the Ergonomic Research Unit of Posture and Movement (EPM) of the Clinica Del Laboro in Milan, Italy. OCRA evaluates and quantifies the risk factors present in the work activity and establishes, through a calculation model, an exposure index from the confrontation between the variables found in the work reality and what the tool recommends as recommendable in that same work environment (Colaco et al., 2015).

In this tool, the quantified risk factors are: duration of work, frequency of technical actions performed, force employed by the operator, inadequate posture of the upper limbs, repetitiveness, lack of physiological recovery periods and complementary factors, such as: extreme temperatures, vibration, use of gloves, mechanical compressions, use of abrupt movements, precision in positioning the objects and the nature of the grip of the objects to be handled (Colaco et al., 2015).

To obtain the Exposure Index (IE) of the OCRA Tool, the number of Technical Actions Observed (ATO) is divided by the number of Technical Actions Recommended (ATR). The result is compared with the risk classification reference to determine the level of action to be taken. To quantify the ATO and ATR it is necessary to apply the criteria and procedures for determining the variables for the calculation, for this, the constant of frequency of technical action must be calculated, the multiplier for strength, multiplier for posture, multiplier for stereotyping (repetitiveness), multiplier for the presence of complementary factors, multiplier for the factor of recovery periods and the multiplier for total duration of repetitive work in the shift (Colaco et al., 2015).

OCRA is divided into checklist and OCRA index and are internationally among the most popular observation-based methods and are included as reference methods in ISO (ISO 11228-3, 2007) and CEN (EN 1005-5: 2007) standards for upper limb risk assessment of repetitive actions. The methods include time-based risk factors such as recovery and frequency and are generally more comprehensive than most other methods. Furthermore, the final risk score, which predicts the risk of developing musculoskeletal disorders, is based on epidemiological research (Rhén; Forsman, 2020).

REBA – Rappid Entire Body Assesment

The REBA tool, was created in 2000 by Hignett and McAtamney, with the aims of: developing a postural analysis system sensitive to musculoskeletal risks in a variety of tasks; dividing the body into segments to be coded individually, with reference to planes of movement; providing a scoring system for muscle activity caused by static, dynamic, rapidly changing or unstable postures; reflecting that coupling is important in handling loads, but cannot always be done by the hands; giving a level of action with an indication of urgency. This requires minimal equipment - pen and paper method (Hignett; Mcatamney, 2000).

REBA was developed to fill a perceived need for a practitioner's field tool, specifically designed to be sensitive to the type of unpredictable working postures encountered in healthcare and other service sectors (Hignett; Mcatamney, 2000).

It presents a postural analysis system sensitive to musculoskeletal risks in a variety of tasks, especially for evaluating work postures found in health care and other service industries. The posture classification system, which included the arms, forearms, wrist, trunk, neck, and legs, was based on the RULA body part diagrams.

The tool reflected the extent of external load/forces exerted, muscle activity caused by static, dynamic, rapidly changing, or unstable postures, and coupling effect. Unlike OWAS and RULA, this technique provided five action levels to assess the level of corrective actions (Kee, 2020).

REBA evaluates posture and external force/loading as well as repeated and static posture effects. In addition, REBA reflects coupling and dynamic loading effects. OWAS does not specify the body parts assessed, but RULA and REBA assess only the left or right side at a time. The three observation methods are equipped with 4 or 5 action categories or levels to decide the risk category (Kee, 2020).

It establishes a simplification in obtaining and analysing postural data, since it is general and sensitive to the handling of loads, and of easy application, which facilitates the cataloguing of most postures adopted by the worker, but does not consider aspects such as vibration and energy expenditure (Souza; Rodrigues, 2006).

IMU – Inertial Mensurement Unit

The development of inertial motion measurement sensors (accelerometers) or IMU, appear in the literature initially for a biofeedback system. This system allows the user to react and correct movement in an incorrect posture position. The addition of visual information provides artificial proprioceptive information about the cranio-vertebral angle. In the pioneering study, six subjects were tested for 5 hours with and without biofeedback. All subjects had a significant decrease in the percentage of time spent in incorrect posture when using biofeedback (Breen et al., 2009).

Recent developments in sensor technology offer potential for regular industrial use, in contrast to other tracking devices such as range cameras or magnetic sensors, which are more effective in virtual environments. For example, an inertial measurement unit (IMUs) is a small, inexpensive, low power device suitable for monitoring the kinematics of a segment in real time. If multiple inertial measurement units are connected, biomechanical models can be developed to capture a wide range of motion (Vignais et al., 2013).

Inertial measurement units (IMUs) are used to reconstruct the posture of the human upper limb. Being independent and non-blocking, IMUs represent a solid alternative to classical optical tracking systems. In addition, the model includes three rotation joints for the shoulder, two for the elbow and two for the wrist. It does not require the mounting of any further instrumentation, such as a camera system. To achieve motion tracking, the system employs sensors in the arm, chest, forearm, and hand. The state of the model, i.e. joint angles, angular velocities and angular accelerations are estimated from measurements coming from IMU sensors (Peppoloni et al., 2016).

4.2. Comparative Study

Table 4 shows the main tools ordered by the volume of publications found, and the NORDIC tool was the most used in the publications, in our understanding due to its easy application, followed by the RULA, REBA and OWAS tools. Another point that would explain the choice is the application, which is the evaluation of musculoskeletal complaints, especially in the upper limbs. The fact that the OCRA tool is not included in this first group can be explained by the greater complexity of the tool, which makes its use less interesting, since it delivers similar results but requires more time for analysis.

The Strain Index tool ranked 10th in the list of publications. When analysing its characteristics, we noticed that even though it is extremely simple to use, its use is reduced because it is not focused on any complaint, which makes it difficult to diagnose the causal link between complaints and the working condition.

As for the focused risk, Table 4 shows that four tools address the repetitiveness aspect, but the observation area and the aspect observed are alternated among them. For example, while OCRA focuses on counting movements and correlates them with postures, Strain Index evaluates the effort itself, making it much more versatile and easier to apply, but its use decreases because it delivers results with low accuracy.

Table 4. Relation of the detected main tools and their characteristics.

Tool	Year of publication	Reference	Evaluation method	Focused risk	Body part observed	Precision	Laboratory x Field Study	Instrument	Costs	Time
NORDIC	1987	KUORINKA *et al.* , 1987	interview or self-application	DORT	General and specific: lumbar, cervical and shoulders	low	laboratory = field study	questionaire	low	average
RULA	1993	MCATAMNEY and CORLETT, 1993	observational	repetitive effort	upper limbs, trunk, neck and legs	low	laboratory = field study	form	low	rapid
REBA	2000	HIGNETT and MCATAMNEY, 2000	observational	force/load, repetitive and static effort	MMSS, trunk, neck and legs	low	laboratory = field study	form	low	rapid
OWAS	1977	KARHU et al., 1977	observational	posture, strength and load	trunk, arms and legs	low	laboratory = field study	form	low	rapid
EMG	1968	FAULKNER, 1968	directly	muscle demand	total	high	laboratory > field study	electromyograph	high	time-consuming
Kinematics	1993	ROEBUCK, 1993	directly	movement	total	high	laboratory > field study	video cameras	high	time-consuming
OCRA	1998	COLOMBINI, 1998	observational	repetitive effort	MMSS	average	laboratory = field study	form	low	average
NIOSH	1981	NIOSH, 1981	observational	load handling	lumbar	low	laboratory = field study	equation	low	average
IMU	2009	BREEN *et al.,* 2009	directly	movement	total	high	laboratory > field study	Inertial Mensurement Unit	high	time-consuming
Strain Index	1995	MOORE and GARG, 1995	observactional	repetitive effort	MMSS	low	laboratory = field study	form and video cameras	low	rapid

Source: Authors. (2020)

Studying the accuracy of the methods, the authors observed that only with the use of technology a high accuracy can be achieved, due to the degree of consistency of the measurements obtained with their average and is related to the proximity between the values obtained by repeating the measurement process (Monico et al, 2009), which does not occur in instruments that use the observation of the analyst.

The application aspect of each of the tools was chosen to differentiate the tools between their use in laboratory versus field study, we noticed that certain tools are more versatile than others, we highlight the EMG, IMU and Kinematic tools for being less versatile. This differentiation was chosen because of the instrumentation of these tools, all three have special aspects of use. EMG uses electrodes attached to the body of the individual being analysed, the most common equipment uses cables that are connected to the equipment, thus compromising mobility. Another aspect is that it is not possible to use these cables in a field application as an activity with machines or even along a manufacturing production line. The UMI instruments are also affixed to the body of the individual and generally do not use cables, which facilitates their use and makes them usable in both conditions, but due to the contact with the individual we believe that they are more interesting for laboratory situations. To carry out a study using kinematics, the analyst can use synchronised camera systems and even devices such as Kinectic - Microsoft. When cameras are used, they must be placed in suitable locations and their use in work environments such as manufacturing is complicated both by other equipment that prevents the individual from being seen and by the space required to provide the distance that the cameras need to focus on the areas of interest.

Table 5. Comparison of human-dependency.

Tool	Evaluation method	Focused risk	Body part observed	human dependency
NORDIC	interview or self-application	DORT	General and specific: lumbar, cervical and shoulders	high
RULA	observational	repetitive effort	upper limbs, trunk, neck and legs	high
REBA	observational	force/load, repetitive and static effort	MMSS, trunk, neck and legs	high
OWAS	observational	posture, strength and load	trunk, arms and legs	high
EMG	directly	muscle demand	total	average
Kinematics	directly	movement	total	low
OCRA	observational	repetitive effort	MMSS	high
NIOSH	observational	load handling	lumbar	high
IMU	directly	movement	total	low
Strain Index	observactional	repetitive effort	MMSS	high

Source: Authors. (2020)

The difficulty increases because these systems require markings to be fixed on the reference articulations of the individual and it is imperative that the individual is wearing clothes such as lycra mesh. Regarding the assessment method, we observed that the EMG and IMU tools are of direct measurement, i.e., they are the only ones in this list that directly assess the variable they have proposed by technology, unlike the others that measure the risks or even the consequences using indirect indicators or markers. The direct measurement has the advantage of less observer participation, i.e., the human-dependence as shown in Table 5.

Considering the advantages and disadvantages of each tool, in Table 6 the authors present the observed aspects. Among the advantages are that each tool proposes to evaluate a certain aspect, which means, that each one is more functional for a condition. As for the disadvantages, they refer to the difficulty of application (instrumentalization), the lack of precision and the limited use of technologies. Another aspect that was evidenced is the limitation in observing the body of workers as a whole, having tools that apply more to certain members and do not apply to others.

Table 6.Comparison of the advantages and disadvantages.

Tool	Advantages	Disadvantages
NORDIC	Diagnostic tool to analyse the work environment; to diagnose work wear, to monitor improvements in the work environment, and for epidemiological studies on disorders musculoesqueléticos	The experience of the person completing the questionnaire may affect the results. Recent and more severe musculoskeletal disorders tend to be remembered more than older and less severe ones. The filling environment and situation may affect the results.
RULA	Easy to apply, serves to screen	Disadvantages of the RULA method include a high-level risk for non-permanent jobs; left and right sides of the body are assessed independently; it does not take into account the time it takes the worker to perform the task
REBA	Simplification in obtaining and analysing postural data, since it is general and sensitive to the handling of loads, and easy to apply, which facilitates the cataloguing of most postures adopted by the worker	The left and right sides of the body are assessed independently, it does not consider aspects such as vibration and energy expenditure
OWAS	Easy to understand and apply, able to fully meet the expectations of professionals. It can be used to ensure a certain ergonomic quality.	Generalist, has low sensitivity regarding the handling of loads, does not take into consideration aspects such as vibration and energy expenditure. It proposes the analysis of posture without considering the cervical region, wrists and forearms. Subjective, as different observers will consider different phases for analysis.
EMG	Assessment of specific musculature use	Difficult to instrument, only functional in the laboratory
Kinematics	High precision, evaluate all movements	Functional only in a laboratory situation, requires adjustments and costly preparation
OCRA	Study of the number of repetitive movements that may present risk of lesion to the MMSS; Quantitative determination of the exposure indexes of risk of lesion to the MMSS; Quantitative exposure index of risk of lesion to the MMSS, making it possible to determine the prioritization of work posts with higher risk.	It does not analyse or quantify the organisational and work regulation constraints
NIOSH	Specialist risk assessment tool. The added benefit of this equation is the potential to reduce other forms of musculoskeletal disorders or injuries associated with some lifting tasks, such as shoulder or arm pain.	It does not include task factors to account for unforeseen conditions such as unexpected heavy loads, slips or falls. It is not designed to evaluate tasks involving one-handed lifting, seated or kneeling lifting, lifting in a confined work space, lifting of persons, extremely hot, cold or contaminated objects or high speed lifting. It assumes that lifting and lowering tasks have the same level of risk.
IMU	Allows field and laboratory use, angle accuracy measurement	Cost, measurement per segment
Strain Index	Useful for analysing tasks and predicting risk potential	It allows the relative risk of a workstation to be calculated and not the exposure risk to which a worker is subjected. The relationship between exposure and the values of the various multipliers is not based on an explicit mathematical relationship defined on the basis of physiological, biomechanical or clinical responses

Source: Authors. (2020)

5. CONCLUSION

Ergonomics professionals have at their disposition the instruments that they call ergonomic tools to evaluate certain situations and quantify or qualify risks and thereby make decisions. This study evidenced 10 of the most cited tools in the literature and described its main functionalities and characteristics, presented its use and its advantages and disadvantages besides elucidating some weaknesses of each one. We then concluded that each of these tools has its intended use and the overlapping of tools indicates a search for new instruments. In the tools it was also observed a great influence of analysts (human-dependency) without the use of digital technology. Additionally, we noticed that the use of digital technology is still rarely applied to work reality in a broad way.

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