Practical implications on ergonomic assessments resulting from EN16710-2—ergonomics methods: A methodology for work analysis to support design

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Abstract: Ergonomic workplace analysis is a basic element of every ergonomic project. In many cases, however, carried out in a fragmented and unstructured manner it gives an incomplete picture of the assessed work processes. Authors on the basis of their own experience and methodologies contained in EN 16710-2 Ergonomic methods—Part 2: Methodology of work analysis to support design, presented the procedure and the most important elements, the conclusion of which enables reliable ergonomic analysis. The key task in the field of ergonomic analysis is to determine the applicability of the data acquisition apparatus under specific conditions, which can be done by analyzing scientific publications or reports from professional literature. An important element of the report is also evidence that the assessment was carried out by a competent person to whom the Euro-Ergonomist institution can be used, or at least by such a person checked. It should also be ensured that the report contains evidence that a sufficiently large part of the system has been tested. Fragmentary analysis is possible as long as conclusions from it are not extended and areas not covered by it. A very important but often overlooked element of ergonomic analysis is the indication of how the project solved incompatibilities (which are an inherent element of almost every research procedure in the area of production). It allows to determine the validity of the inference based on the collected material, as well as to determine deviations from the applicable standards. The article also presents the method of triangulation as an element of protection against incorrect diagnosis of the method of work implementation.

Key words: ergonomic analysis, project management, work safety management, ergonomic design

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1. Introduction

The growing demand for safe and ergonomic working conditions, further strengthened by demographic changes, forces enterprises to implement systems that allow managing work effects (Butlewski and Misztal, 2016, p. 72). Among the negative effects of work, one of the more important groups are

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musculoskeletal disorders (Work-related Musculoskeletal Disorders—WMSDs). For this reason, companies are increasingly deciding to invest in improving working conditions. However, in order for them to hit and give the assumed effect, they must be preceded by a thorough analysis in order to identify the main factors affecting the reduced ergonomic quality at the workplace.

The aim of the article is therefore to present the methodology of ergonomic analysis based on the PN-EN 16710-2:2016-05. Ergonomic methods—Part 2: Methodology of work analysis to support design, which significantly supports the processes of analyzing working conditions. Based on the standard, the authors have identified key factors conducive to conducting reliable ergonomic analyzes, supporting this with the proposal of setting ergonomic goals in projects and including in the organization structure of projects in the enterprise consultancy in ergonomics—at the organizational level (creation of the Ergonomics Commission) or external (specialist, e.g. Euro Ergonomist).

2. Ergonomic analysis as part of project management

In modern enterprises, attempts are being made to solve existing problems by creating and managing projects. This allows categorization and structuring of undertaken activities, and also favours the selection of personnel most adequate to ensure the success of the project. Appropriate division of tasks is conducive to the optimal use of the potential of the project team members and allows for an unambiguous division of responsibility for achieving the objectives set.

Increasingly, ergonomic analyses are components of projects in enterprises, which may constitute the main element of the project (ergonomic design) or be part of other ongoing projects (e.g. construction, reorganization of workplaces, related to the occupational health and safety management system, consisting in planning the use of new machines and work tools). Regardless of the purpose of undertaking ergonomic analyses within projects and project management methods, e.g. PMI, SCRUM, TenStep (Ćwiklicki, 2010, p. 18; TenStep Polska, 2018), their management can be an element of project management and should be included in the schedule and allocation of resources. As part of project management in terms of ergonomic analysis, measurable goals should be identified along with aggregation measures, control points and ways of verifying the results obtained in individual stages of the project should be established (Figure 1).

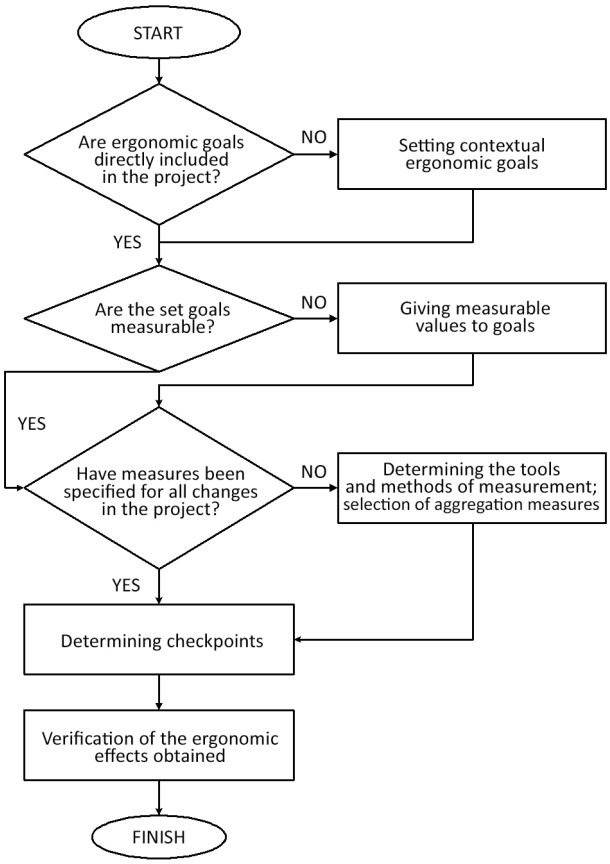

Figure 1. Algorithm for selecting assessment tools in project management

S o u r c e: Authors' own elaboration.

In enterprises that do not employ people competent in the field of ergonomics, but undertake (or plan to undertake) ergonomic projects as part of their activities, there may be difficulties in project management resulting from:

– lack of personnel with the knowledge necessary to conduct the analysis and incorporate the applications into the key stages of the project (in this case it is necessary to extend the project team by an external person);
– problems in estimating the necessary financial and material resources to perform ergonomic analysis;
– problems in integrating ergonomic analysis with other project assumptions to achieve the set goal;
– problems arising from the determination of the significance of individual results of ergonomic analyses (only selection of results to achieve the goal set in the conceptual phase).

The above difficulties should be taken into account in project management, therefore it is proposed to take actions related to ergonomics (embedded in the generally accepted framework for organizing and conducting projects) in accordance with the following model (see Figure 2).

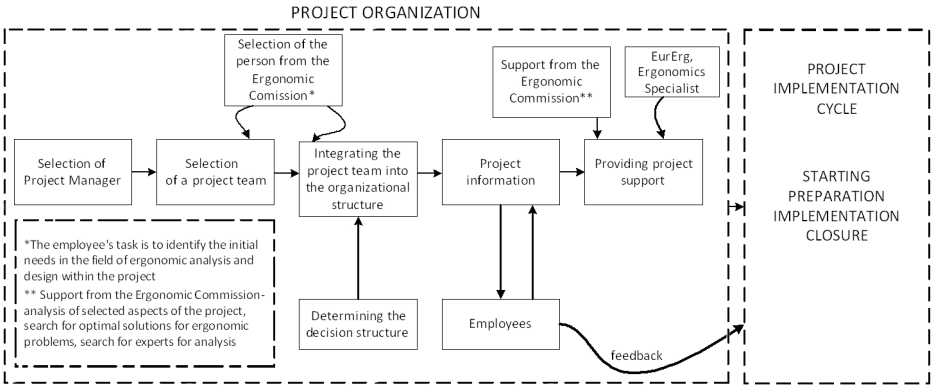

Figure 2. Elements of management through ergonomics against the background of the preparatory process of the project

S o u r c e: Authors' own elaboration based on Wyrwicka, 2011.

The key element is to include in the project team a person associated with the enterprise's ergonomics unit or an employee with knowledge and skills to support the project at individual stages, whose task will be to identify the needs of ergonomic analysis. Such a person would also provide support for the project, including problem analysis and solutions, and seeking external experts (if necessary).

3. The algorithm of conduct in the analysis of work processes

When carrying out an ergonomic analysis of the work process, information on various aspects of the work process (e.g. work environment, its organization, how tasks are performed) should be recognized. It is also necessary to collect data on the individual predispositions of the employee (e.g. age, seniority, gender, physical activity, professional experience) and contextual aspects needed to conduct the analysis in accordance with the selected methods or tools (Figure 3). An example of such a contextual and insignificant factor is the commute time, which completes the information on the gross length of the working day.

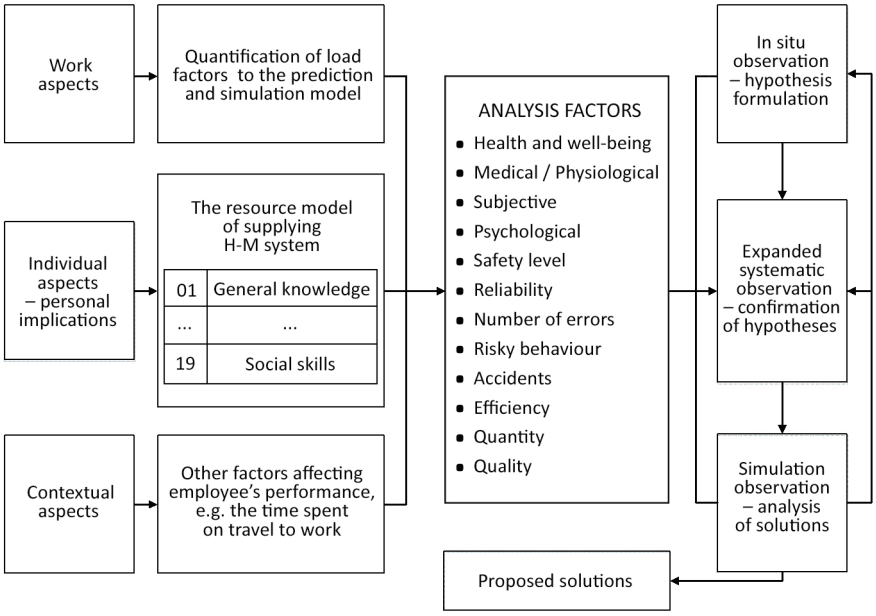

Figure 3. Practical implications for conducting ergonomic audits

S o u r c e: Author's own elaboration based on EN 16710-2 and the resource model from Butlewski, 2018.

Contextual analysis of the work allows the identification of factors that are the subject of further considerations, leading to the formulation and confirmation of hypotheses, which is then the basis for proposing solutions that ergonomically shape the working conditions.

It should be remembered that the process of ergonomic analysis should take into account the real activity of the employee during work (Figure 4), because it may differ from the assumed values. This fact may result, for example, from the individual physical and health conditions of the employee, affecting the manner and pace of performing individual activities, the lack of effectiveness of some organizational solutions in the work process, and the informal division of individual tasks between employees.

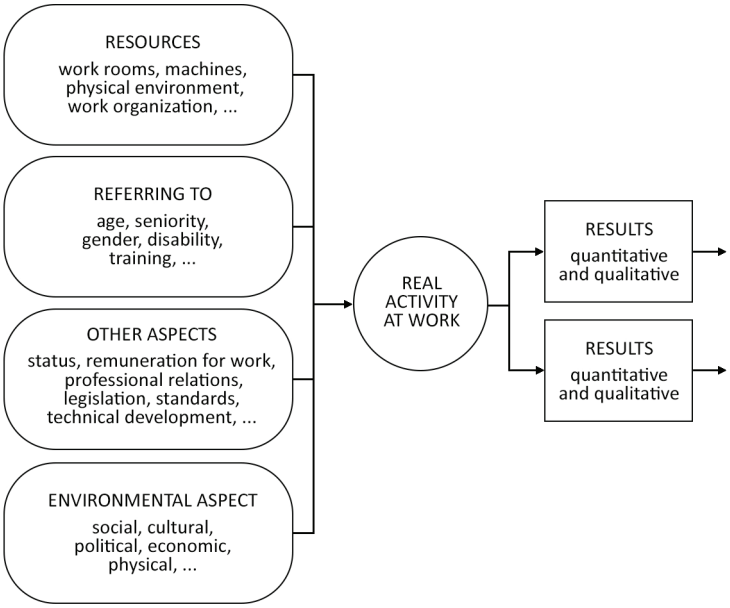

Figure 4. Components of the employee's actual activity at work

S o u r c e: Authors'own elaboration based on the EN 16710-2 standard.

In the analysis process, depending on the methods and tools used, it is possible to obtain information on the employee's work load in the form of a qualitative or quantitative result. Methods and tools should be selected before the start of the analysis, depending on the type of position, the possibility of collecting data necessary to carry out the correct analysis and the purpose of conducting it, which may be, for example, examining the impact of the employee's load on the efficiency and quality of his work or health and safety.

If irregularities are found during the ergonomic analysis, an in-depth analysis should be performed. For this purpose, additional, missing information should be collected by repeatedly observing the environment or use data previously used for the analysis, if it is sufficient. Then, an analysis of the possibilities of eliminating these irregularities should be carried out or ways should be developed to reduce their impact on the employee's burden. At this stage, solutions should be simulated, e.g. by re-analyzing the impact of the work process (using the method previously used) on the employee's burden, taking into account the solutions proposed, and assessing their impact on the overall result of the analysis. This allows to choose the optimal solutions that limit the negative impact of the work process on the employee not only because of their effectiveness, but also because of the cost of their introduction and maintenance.

4. Guidelines for ergonomic audits

In European countries, one of the most common ways to reduce the impact of factors adversely affecting the health of employees is to conduct cyclical ergonomic audits. On their basis, it is possible to monitor the current state of ergonomics of the surveyed workstations and to present proposals for solutions aimed at improving the segments in which unsatisfactory results were obtained.

The audit report should contain the following elements (according to EN 16710-2 standard):

– an indication of what standards have been applied and justification for choosing these standards;
– evidence that the assessment was carried out by a competent person, as appropriate for the procedure;
– evidence that a sufficiently large part of the system (in the workplace or elsewhere) has been tested to ensure reliable results for the entire system;
– description of identified non-compliances and how to limit or eliminate them;
– justification of deviations from applicable standards and practice in the field of ergonomic analysis.

Correct ergonomic analysis therefore requires the auditor to gather sufficient data. In order to obtain information on the assessed workstation, objective and subjective methods are used. Objective methods are aimed at presenting and assessing the state of ergonomics at a given workplace in a manner consistent with the actual state, regardless of the opinions and feelings of employees. Objective methods of obtaining information include making measurements, observations and reviewing the documents necessary for the proper functioning of the examined area. The auditor usually first proceeds to review documents in the audited entity. This serves to assess the state of ergonomic solutions in the company by performing an analysis of the company's procedures and meeting legal requirements and standards set for a given type of work. The auditor, as a result of analyzing documentation, is required to compare the collected data with the standards and guidelines in force in national law with international standards, if they introduce more restrictive provisions. The documentation also shows who is the decision maker in the context of the recommended solutions that should be implemented in the company. All procedures and diagrams describing the position and the employee performing specific tasks are subject to analysis, demographic and contextual data are also indicated, which include the frequency and severity of accidents and the number of reported occupational diseases. As a result of the documentation review, the measurable parameters of the working environment are also assessed. Audited measurements should be performed in advance by competent auditors, using appropriate equipment and techniques. It is also important to consider not only individual elements of the physical environment, but also take into account the synergy effect that can occur as a result of combining several factors.

A comprehensive analysis of the work process also includes the subjective feelings of employees that are examined using questionnaires and interviews. Employees should therefore be involved at every stage of the analysis (Burgess-Limerick, 2018, p. 91). Information collected in an interview with an employee can be considered reliable only if it is properly

performed. Questions asked to the employee should be short and unambiguous, and also formulated using simple vocabulary known to the employee. The questioned person has the opportunity to answer precisely and truthfully when the question is fully understood. Therefore, the auditor must take into account that when an employee has a problem with the correct interpretation of a given question, it is usually better to ask it differently than to repeat it in the same form. It is also good practice to ask the operator a question again to confirm that the auditor understands the answer correctly or as a way to get more information. Examples of questions an auditor may ask an employee during an interview are listed below:

– "I noticed you move often to see the product. Can you explain why?";
– "Is your work always done in the same way?";
– "Why did you touch the machine cover?";
– "What do you do in the event of a machine failure?";
– "What happens if you fail?";
– "What is the most tiring in this job?";
– "Is there anything else you would like to talk about?".

The notes formulated during both the observation and the interview should be consistent with the actual state and the statements of the questioned person, without reformulation or interpretation by the auditor. It is recommended to literally quote the employee's words and then interpret them, which reduces the risk of distortion. This requires confidentiality and employee consent. Notes and recordings should be destroyed when the analysis process is completed. Comparisons between sources (individual employees) usually confirm the information gathered during interviews, however possible conflicts should be taken into account. Another important activity during an ergonomic audit is the observation of the workplace by the person conducting the audit. The literature on the subject distinguishes three types of observation: initial, extended (systematic) and simulated. The first of these aims to collect basic information about the employee, such as: gender, age and qualifications, work schedule. It is also important during initial observation to determine the resources necessary to perform activities at the workplace: tools, materials and equipment used. The workspace and environmental factors such as noise, lighting, vibrations and dust should also be taken into account when conducting the initial observation. On the other hand, if there is more than one operator at the workstation, the division of tasks between employees and the synchronization mode should also be analyzed. The auditor should pay special attention to verbal communication, gestures and signals made by employees as well as communication barriers.

Extended observation should be performed using structured methods of ergonomic analysis, such as REBA, RULA or ERA (described in the next chapter). By using these tools, it is possible to determine the physical and task load of an employee, as well as to determine the direction of looking, moving and posture. When conducting this type of observation, it is possible to register incidents and ways of solving them, which indicates dysfunctions, job variability or operator competences.

5. Types of ergonomic methods and the scope of their application

For the analysis of ergonomics at workstations, a various set of available methods or a certain combination thereof (selected depending on the type of work performed at the workstation, the method of its performance and the required accuracy of analysis) can be used. Table 1 presents the characteristics of selected methods, including the area of their application and restrictions resulting from the assessment parameters and the possibility of analyzing factors other than those related to the position adopted by the employee during work.

Table 1. Selected methods used in ergonomic analysis

Designation	Application	Restriction
MSD Hazard Risk Assessment Checklist	Checklist to assess the risk of musculoskeletal disorders in employees. It allows to evaluate many work parameters—from the position at work, including the location of individual body segments, to determine the impact of vibration, stress (grip, lifting, pushing) at risk level. The advantage of the method is a simple design that allows rapid evaluation of the desired parameters (OHSCO, 2007).	It is recommended that the use of the checklist be a preliminary analysis of the occurrence or absence of a specific type of factors at work that may affect the development of musculoskeletal disorders in employees. The results of the assessment can be used to plan further analysis using more advanced methods. The method should not be used in the case of: job evaluation after the employee's return, selection of employees for the job, assessment of the relationship of work with the injury (OHSCO, 2007).
Washington Ergonomics Assessments	The method used for the initial analysis of ergonomic risk factors, mainly at workplaces in the manufacturing industry. The assessment covers, among others working movements performed during work, position of upper limbs and torso during work, as well as additional factors, e.g. vibrations. It also evaluates the opinions of employee performing activities regarding their difficulties (WSPS, 2011).	The method is recommended for the initial analysis of ergonomic risk factors—additional tools are required to perform a reliable assessment. The method does not take into account the assessment of pushing force and leg position.
Washington State Checklists (Caution/ Hazard Zone)	Checklist for assessing the occurrence of risk factors for employees at work. It is possible to identify weird positions at work with their repeatability and duration (over 4 hours per shift), position of specific body segments during work, highly repetitive work movements, repetitive impact of a specific way of performing work on the occurrence of employee complaints (Robledo Gallegos, 2010; WSDL&I, 2018).	The method only gives the possibility to indicate that a given risk factor occurs without point evaluation, which may result in the need for other methods to support the analysis.

Designation	Application	Restriction
ACGIH: Lifting TLV	The method allows determining the recommended organization of the workplace at which manual lifting is performed. During the assessment, the permissible masses of weights are determined, taking into account: the duration of lifting (per shift) and the frequency of repetitions. It is also possible to take into account additional factors, such as: extended working shift, large lifting asymmetry and working conditions, e.g. humidity or temperature (Nelson & Associates, 2010).	The method does not take into account grip and pushing forces, vibrations and stresses. It is impossible to determine the risk factors associated with the position of the upper limbs and legs during work.
NIOSH Lifting Equation	A method of assessing work requiring weight transfer during work, used for two-handed, symmetrical or asymmetrical work. Using the equation allows to determine the optimal value of the mass of the transferred goods (Middlesworth, 2012).	The method does not take into account grip, pushing forces, and vibrations. It is impossible to determine the risk factors associated with the position of the upper limbs and legs during work. It is also impossible to use it when lifting with one hand, in the case of a work shift lasting over 8 hours, with high frequency of repetition of working movements and in the case of work carried out in a squat or sitting position.
Snook Tables	Tables for risk analysis, providing the opportunity to assess the psychophysical parameters of work and find a percentage of the population able to sustain a given effort. The assessment covers: lifting, pushing and pulling, moving loads (*Using the Snook Push/ Pull Tables*, 2018).	The method does not take into account grip strength, vibration and body stress nor the position of the hands and wrists during work. Using tables requires evaluation experience.
MAC (UK)	A tool that allows to identify risk factors at workplaces, generated by lifting and moving (also team) loads during work. The results indicate which transfer or lifting operations require action to reduce the workload of the employee (HSE, 2018).	The method does not take into account the force of pushing and grip, vibrations and body stress. It also does not take into account the position of the hands and wrists during activities, and the position of the lower limbs is not assessed.
ACGIH: HAL	A method of assessing the risk associated with monotypic, repetitive activities lasting less than 4 hours per work shift (Nelson & Associates, 2010).	The method only takes into account the position of the hand and wrist during work, it also does not take into account additional factors, such as vibrations, stresses, the employee's attitude during work.

Designation	Application	Restriction
RULA	The method is used to assess the employee's effort during work related to body position, including the position of the torso, head, shoulders, forearms and wrists and hands. The method enables evaluation of position repeatability over time (Rivero, Rodríguez, Pérez, Mar and Juárez, 2015).	The method does not apply to workplaces where work is carried out in a standing position (it is not possible to assess the position of the legs). The method does not take into account parameters other than those related to the position and load of the employee, e.g. work rhythm, or non-work-related factors that burden the employee, which may affect the way the work is performed, e.g. stress. It also doesn't take into account vibration, stress, gripping force and lifting.
Strain Index	Ergonomic risk assessment method, which includes the assessment of the position of the hand, wrist, forearm and elbow (Moore and Garg, 1995). The following parameters are assessed: intensity and duration of the effort, position of the hand/ wrist during work, speed of work and duration of the task per working day (Budnick, 2014).	The method does not take into account the impact of vibrations (which in the case of working with tools generating them significantly influences risk evaluation). Stresses are also not included. The method does not allow identification of distal neuromuscular disorders of the upper limb. The limitation is also the high subjectivity of the assessment—half of the parameters are estimated only on the basis of the evaluator's experience (Michael, 2002).
CTD Risk Index (CTD-RAM)	A method for assessing the ergonomic risk associated with loading the upper limb during work. The following parameters are subject to evaluation: cycle repeatability, gripping/ lifting/ pushing forces, the method also takes into account additional factors such as: contact with sharp edges, vibrations, type of action taken (dynamic, static, moderate), temperature (cold, heat) (CTD Risk Index, 2018).	The method is limited to assessing work in terms of upper limb load. It may also be characterized by inaccuracy, due to the fact that some parameters are assessed only in terms of their occurrence or not.
LUBA	A method of assessing postural loads, taking into account the assessment of position during work, including the position of the neck, shoulders, hands and wrists and back (Kee and Karwowski, 2001, p. 359).	The method has many limitations. First of all, it does not take into account the repeatability of the actions performed by the employee and their duration, and neither the gripping force, lifting nor pushing can be determined. The method does not take into account the impact of vibration and stress on the ergonomic risk associated with the work performed, and it is not possible to evaluate the position of the legs.

Designation	Application	Restriction
OCRA	A method used to identify the load on the musculoskeletal system (upper limbs) of an employee in repetitive activities (Roman-Liu, 2002; Occhipinti, 1998, pp. 1290–1311). It includes vibration, lifting, gripping and pushing. Ergonomic risk assessment using this method can be carried out according to the guidelines of the EN1005-5: 2007 standard (Roman-Liu, Groborz and Tokarski, 2013, p. 1584).	The method focuses on determining the position of the forearm, without taking into account the position of the arm. Strength assessment can be subjective. The position of the forearm and hand can only be described as 'good' and 'bad', which is a limitation on the accuracy of the results obtained (Roman-Liu, Groborz and Tokarski, 2013, p. 1584).
QEC—Quick Exposure Check	A method of assessing physical and psychological risk factors associated with positions taken by an employee at work, consisting of observation and self-reporting. It allows to assess the strange positions of the neck, back, shoulders and hands/ wrists (Li and Buckle, 1998, p. 1353). It takes into account the repetition of activities, lifting, working time, the use of tools that generate vibrations, as well as the pace of work and stress (Erdinç, 2015, p. 429).	The assessment of the pace of work and stress is characterized by a large dose of subjectivity. The authors of the method did not take into account the guidelines regarding risk targets.The method does not take into account grip forces and values of pressures, stresses and impacts.
REBA	The method is used to assess the employee's effort during work related to body position, including the position of the torso, legs, head, shoulders, forearms and wrists and hands (Hignett and McAtamney, 2000, pp. 201–205). The method allows the assessment of position repeatability over time and additional employee load, e.g. lifting (Roman-Liu, 2009, p. 12).	Application of the method is difficult for positions where work is performed in a sitting position. The method does not take into account parameters other than those related to the position and load of the employee, e.g. work rhythm, or non--work-related factors that burden the employee, which may affect the way the work is performed, e.g. stress. It also doesn't take into account vibration, stress, grip strength.
ERIN	A method of assessing an employee's postural loads, including the assessment of the position of the torso, shoulders, wrists of the hands (including the frequency of taking the position) and neck. Additionally, the speed of work, effort at work and the level of stress experienced by employees (self-assessment) are assessed (Rodríguez, Viña and Montero, 2013, p. 64).	The application of the method does not allow the assessment of ergonomic risk, including the lifting of objects during operation. The assessment of rhythm (speed of work) and stress at work is characterized by a large dose of subjectivity.

Designation	Application	Restriction
ManTRA	Matrix method of assessing the load on the musculoskeletal system of individual body segments during work taking into account the duration of activities, vibrations, strength and speed of tasks. Based on the assessed risk, it is possible to propose corrective solutions (Straker, Pollock, Burgess-Limerick and Egeskov, 2007, pp. 21–22).	The method does not allow to take into account pressures, stresses and impacts. The assessment may be characterized by a large dose of subjectivity, e.g. vibrations are assessed only in terms of their occurrence and not according to specific ranges of values.
OWAS (Ovako Working Posture Analysis System)	A method for assessing the ergonomic risk of musculoskeletal disorders. The assessment covers: the position of individual body segments (torso, arms, legs), exerting force, estimating the position of the body as forced or unforced (Karhu, Kansi and Kuorinka, 1977, p. 200). Risk assessment is based on work timing (Roman-Liu and Tokarski, 2010, p. 28).	The method does not take into account the assessment of the position of the hand and wrist, which is why it cannot be used to assess e.g. precision work, it also does not take into account vibrations, pressures, stresses and impacts.

S o u r c e: Authors' own elaboration based on sources indicated in the 2nd and 3rd column.

It should be noted that the restrictions on the use of selected methods indicated in the table above are not a complete statement. During the assessment of the workplace, obstacles unforeseen by the assessors may appear, preventing the application of the tool for a given type of work.

6. Conclusions

The constant pursuit of humanization of work and shrinking employee resources mean that ergonomic changes in the workplace are not only the good will of the employer but also a necessity. Therefore, enterprises should implement properly adapted ergonomic methods in their management systems, which will ensure the desired orientation of implemented changes. According to the authors, it is advisable in this context to use practical guidelines from applicable legal provisions and standards. Accessible for interpreters, the interpretation of the records (as indicated on the example of the EN 16710-2 standard) can significantly help enterprises in implementing changes. In addition, structuring ergonomic analyzes and dividing them into stages favours the possibility of including them in various projects undertaken as part of business operations (also directly not related to ergonomics and occupational safety). The authors' suggestion is to implement ergonomic advisory units in enterprises that take part in the implementation of projects at various stages.

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Praktyczne implikacje dla analiz ergonomicznych w zarządzaniu projektami wynikające z normy EN 16710-2 Metody ergonomiczne. Metodyka analizy pracy wspierająca projektowanie

Abstrakt: Ergonomiczna analiza stanowisk pracy jest podstawowym elementem każdego ergonomicznego projektu. W wielu przypadkach jednak przeprowadzana w sposób fragmentaryczny i nieustrukturyzowany, daje niepełny i mylący obraz ocenianych procesów pracy. Autorzy na podstawie własnych doświadczeń i metodyk zawartych w *EN 16710-2 Metody ergonomiczne – Część 2: Metodologia analizy pracy do wspomagania projektowania* przedstawili sposób postępowania i najważniejsze elementy, których zawarcie umożliwia rzetelną analizę ergonomiczną. Wskazano kluczowe elementy analizy ergonomicznej, którymi są: (1) ustalenie zastosowalności aparatu pozyskiwania danych w określonych warunkach, (2) zastosowanie triangulacji w stosowanych metodach badawczych, zarówno w analizie jakościowej, jak i ilościowej, (3) dobór odpowiedniej części analizowanego systemu, a w przypadku analizy fragmentarycznej zapewnienie przenoszenia wniosków jedynie na obszary nią objęte. Bardzo ważnym, aczkolwiek często pomijanym elementem analiz ergonomicz-

nych jest wskazanie, w jaki sposób rezultaty związane z realizacją projektu przyczyniły się do rozwiązania problemów niezgodności, które są inherentnym elementem prawie każdego postępowania badawczego w obszarze organizacji pracy. Pozwala to na ustalenie, na ile zasadne jest wnioskowanie na podstawie zebranego materiału, a także ustalenie odchyleń od obowiązujących standardów. W artykule przedstawiono również schemat zarządzania przedsięwzięciami, tak aby uzyskiwane mogły być kontekstowe cele ergonomiczne.

Słowa kluczowe: analiza ergonomiczna, zarządzanie projektami, zarządzanie bezpieczeństwem pracy, projekt ergonomiczny