

State of the art of ergonomic costs as criterion for evaluating and improving organizational performance in industry

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Abstract

This study selects, in a structured manner, relevant articles with scientific recognition and simultaneously identifies these publications' characteristics that may scientifically enrich the proposed topic. The topic involves ergonomic costs as a criterion for evaluating and improving organizational performance in industry. This study uses Proknow-C as a theoretical instrument for intervention. The following results are obtained: a) a bibliographic portfolio of 16 items, aligned with the view adopted by researchers who served as this research's theoretical framework; b) the Applied *Ergonomics* journal shows the highest number of scientific articles in the bibliographic portfolio; and c) Ergonomics, Costs, and Evaluation are the most frequent keywords. The studies selected using the methodology indicate that successful ergonomic projects result in substantially reduced production costs and associated economic and financial gain for the industry.

Keywords: Performance Evaluation; Costs; Ergonomics

Estado del arte de los costos ergonómicos como un criterio para la evaluación y mejora del desempeño organizacional en la industria

Resumen

Esta investigación tuvo como objetivo seleccionar de una manera estructurada, artículos relevantes con reconocimiento científico y, al mismo tiempo, identificar las características de las publicaciones que puedan contribuir científicamente para el enriquecimiento del tema propuesto. El tema objeto de estudio se dirige a la gestión de los costos como herramienta ergonómica de evaluación del desempeño en la industria. El trabajo se caracteriza como exploratorio-descriptivo, de naturaleza teórico-ilustrativa, y tiene como instrumento teórico de intervención el Development Process–Constructivist (Proknow-C). Como resultado de este proceso se encontró: a) un portafolio de 16 artículos, alineados con la opinión adoptada por los investigadores, que sirvieron como marco teórico básico de esta investigación; b) el diario *Journal Applied Ergonomics* como aquella que tiene el mayor número de trabajos en el Portafolio Biblioteca; c) Ergonomics, Costs y Evaluation, como las palabras-clave más frecuentes. Los estudios seleccionados por metodología indican que proyectos de ergonomía exitosas resultaron en reducción sustancial de los costes de producción con una ganancia económica y financiera consecuente para la industria.

Palabras Clave: Evaluación del Desempeño; Costos; Ergonomía

1. Introduction

One of the biggest mistakes of managers is to link ergonomics exclusively to health and safety of workers when it should also be added to the organization's planning cycles to ensure good business performance. According to Dul and Neumann [1] and Falck et al. [2], ergonomics should be an

integral part of organizational strategy—combining employee health and safety objectives and economic goals, thus generating value for shareholders and employees.

Working conditions in the industrial sector have motivated numerous studies on the impact of ergonomics on the financial performance of these organizations. Good ergonomic conditions are intrinsically linked to employee

satisfaction, high productivity, and reduction of cost offsets for accidents or occupational diseases. In the specialized literature, there is a consistent research body that demonstrates the benefits of ergonomics to organizational performance [3-5]. The financial benefits resulting from the implementation of ergonomic programs are visible in both industrially developed countries and the ones that are still industrializing. The benefits of ergonomics are most visible in the latter group [6].

Most literature recognizes that ergonomics should be included as a criterion for evaluating and improving organizational performance, considering factors such as the health and safety of workers and increasing or maintaining productivity and quality levels.

The subject of ergonomic cost is constituted by comprehensive and complex lines of research, highlighting the difficulties in undertaking a study related to this subject. There is an additional difficulty related to amplitude and dispersion of knowledge in various publications, editors, and databases. In this respect, Tasca et al. [7] reported the difficulty that many researchers face in justifying the selected theoretical framework to support their research activities. This situation indicates the importance of using a structured method that provides a consistent theoretical framework.

In this respect, the researcher is faced with the following question: how to build the required knowledge when beginning a search on the subject of ergonomic costs, in order to later allow the researcher to seek opportunities to contribute to this subject?

In response to this question, this paper's main objective is to guide the researcher in the search of opportunities (gaps) on the chosen topic.

The selection of a relevant literature portfolio on the topic; conducting bibliometric analysis of the selected bibliographic portfolio and its references; and seeking to identify the important journals, articles, authors, and keywords are the specific objectives of this study.

Thus, through a structured process, known as ProKnow-C (*Knowledge Process Development-Constructivist*), this study selects relevant articles with scientific recognition and identifies aspects of these publications that contribute to the topic.

2. Performance Evaluation in Industry

In business management, the importance of performance evaluation has long been recognized as an integral part of the planning and control cycle of organizations. Performance evaluation is fundamental to the effective management of human resources, assisting in the development of individuals, improving organizational performance, and contributing to business planning [8]. Although several authors have undertaken efforts to develop more efficient methods to measure performance, there is still much criticism against traditional means of assessment. The incentive for short-term approaches, narrow focus on strategy covering quality, insufficient stimulus of the adoption of measures to encourage continuous improvement, and the scarcity of information about customer needs and performance of the competition are some of the major identified deficiencies [9-12].

The assessment of organizational performance can be conceptualized as the management process used to build, establish, and disseminate knowledge through the identification, organization, measurement, and integration of necessary and sufficient aspects to measure and manage the performance of the strategic objectives of a particular context of the organization [13]. There are several tools that can assess the performance of organizations. *Performance Pyramid System* [14], and *Performance Prism* [15] are well-known and disseminated methodologies in the academic and business environment. Although these methodologies have advantages in meeting aspects of the new decision-making context, they fail to meet the requirements regarding the identification, organization, measurement, and integration of criteria, as well as the generation of improvement actions [13].

Concerning the specialized literature, performance evaluation systems should include the use of financial and non-financial indicators, especially because many factors that can be evaluated are currently considered to be intangible. Furthermore, evaluation systems of organizational performance should consider the particularities of the context in which the assessment will occur, through the values and preferences of the *decision-maker*, and thus permit the connection between operational and strategic objectives. The historical use of performance evaluation criteria solely based on financial ratios gives way to the use of more appropriate parameters to the new reality of organizations. In many situations, non-financial indicators such as the quality of products and services, customer satisfaction, cycle time, innovation, psychosocial environment, musculoskeletal health, and employee effectiveness are now being considered [16-19].

In many cases, however, ergonomics is still neglected by industry in the planning and implementation of actions aimed at measuring and improving business performance. The poor knowledge of managers about ergonomics and the difficulty in measuring its financial benefits discourage its inclusion as a criterion for evaluating and improving performance [20-22].

Ergonomics is found at the base of the performance improvement process, enabling increased productivity, improved product quality, reduced failures, and as a consequence, cost reduction. Generally, improvements in ergonomics bring measurable benefits for production processes, such as improvement in productivity, which can be translated into financial results. In a study on drilling steel plates, comparing the productivity of an ergonomically redesigned workstation with a conventional workstation resulted in increases of 22% in volume and 50% in the quality of holes performed by workers [23, 24]. When considering the advanced manufacturing technology (AMT), a widely used feature in modern industry, Maldonado et al. [25] proposed a new methodology for evaluating AMT incorporating human factors and work ergonomics. Similarly, Craig *et al.* [26] emphasized that harm reduction programs in industry must go beyond traditional methods for risk factors of work-related ergonomics. These should include personal factors such as smoking, weight control, and alcohol abuse.

2.1. Measurement of Ergonomic Costs in Industry

In the literature, several studies were identified that measured ergonomic costs and their importance for the evaluation and improvement of organizational performance in various industry sectors. Sen and Yeow [27] conducted a study to ascertain whether ergonomic improvements can have their financial feasibility proven in developing countries. In this study, we identified that the improvements that would have saved over US\$ 500,000 in the first year and the improvement costs were less than 2%. Thus, we concluded that the ergonomic proposal was quite profitable for the organization. Also, in a study conducted in an office environment, collecting outcome measures after a macro ergonomics intervention showed significant positive effects on employees, such as improved communication and collaboration and efficiency of business processes-time and cost [18].

Furthermore, Yeow and Sen [28] reported that ergonomic interventions performed on the production line of an electronic components factory solved problems such as delay in search for materials, unproductive manual counting of components, obstructions during inserts, and the falling of components while the plate is transported on a conveyor belt. The results revealed the effectiveness of ergonomics applied to the manual component insertion (MCI) process, generating a considerable increase in productivity and annual revenue (US\$ 4,223,736) and a reduction in defects and annual waste costs (US\$ 956,136).

Several authors indicate that organizations are reluctant to adopt ergonomic interventions, particularly due to the difficulty in measuring their financial impacts [29]. Thus, the search for the economic measurement of ergonomic costs in industry by researchers is noticeable. Hendrick [20] argues that managers only financially support an ergonomic design when grounded in a cost-benefit analysis. For this, the author reported 250 case studies of the benefits of ergonomics programs, including the reduction of musculoskeletal disorders, missed work days, cost of worker compensation, increased productivity, quality, and business volume. The author concluded that the payback period for ergonomic interventions was less than one year. Similarly, studies conducted with workers in the newspaper industry reported that the implementation of ergonomic designs to reduce musculoskeletal injuries had a low average cost of US\$376 and US\$25.

In the clothing industry, the economic evaluation from a participatory ergonomic process showed that ergonomic interventions can be economically advantageous, even when changes are low financial cost and technological. [30]. Trask *et al.* [31] innovated by proposing the measurement of costs related to the data-collection phase of studies involving ergonomics costs. The results showed that the collection method based on self-reporting by workers is less costly. Similarly, the use of a virtual simulation tool for the simultaneous application of evaluation methods of ergonomic hazards in static and repetitive activities in the metal industry favored making business decisions with consequent reduction of costs and investments [32].

Therefore, there are serious difficulties in quantifying the financial loss to industry, due to problems caused by the absence of appropriate ergonomic conditions. However, the economic benefits of ergonomics can easily outweigh its implementation costs, and that the financial losses relate mainly to the reduction in the productivity of workers in the manufacturing process [33]. The main difficulties in measuring these losses are related to the cost and lack of information, the multifactorial nature of the problems, and measurement methods [34,35]. Rickards and Putnam [22] provide an accounting-based methodology to identify potential productivity gains from the adoption of ergonomic improvements in a *call center*. The analyzed factors were absenteeism, overtime, costs for training new workers, processing time of missed calls, and lost productivity.

It is also possible to find studies related to the measurement of ergonomic costs in industry jobs in the Brazilian literature. A study performed in the shoe industry about the cost benefit of an ergonomic intervention demonstrated that the gains achieved were higher than the intervention costs. The study also showed that, after the intervention, there was an 80% reduction in accidents, 45.65% reduction in absenteeism, and improved production with a 3% increase in productivity and a reduction in manufacturing wastes (reworking and wastes) to less than 1% [36].

3. Materials and Methods

3.1. Intervention instrument: Proknow-C

The knowledge construction process critical to conducting a survey is unique in relation to the researcher and the boundaries imposed for the research. Also, the context in which the researcher is inserted, and the availability of access to the means of dissemination of research, influences this knowledge construction process [37,38].

As an intervention tool, the survey used a literature review process called ProKnow-C, proposed by Ensslin *et al.* [7], which, from a constructivist perspective, shows a structured process to build the needed knowledge in the researcher to begin research on the subject they want to investigate (Fig. 1).

ProKnow-C was conceived in the Laboratory for Multicriteria Methodologies to Support Decision Making (LabMCDA) under the Department of Production and Systems Engineering, Federal University of Santa Catarina (UFMS), Brazil, which since 1994 has investigated the subject of organizational performance evaluation as a tool for supporting decision-making, using the Multicriteria methodology to Support Constructivist Decision Making (MCDA-C). LabMCDA found, however, that the materials that informed the review of the state of the art of its publications could be questioned in relation to alignment and relevance of the content related to the purpose of the research as well as the completeness of the search for these materials.

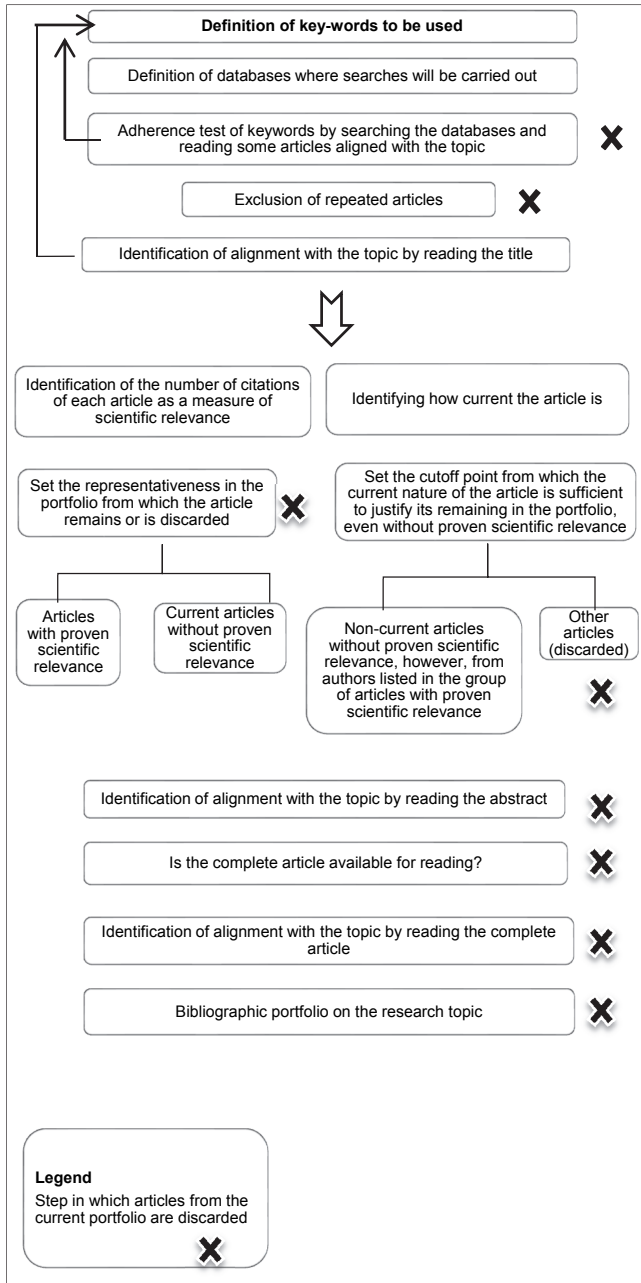


Figure 1. Summary of the selection process of the bibliographic portfolio in the ProKnow-C knowledge construction methodology. Source: Adapted from Tasca *et al.* [7].

Thus, in 2005, LabMCDA launched a line of research to fill this gap by developing a process that performs the search with bounded amplitude. The framework provided by the researchers oriented the structured process and the focus. Currently, ProKnow-C has several publications in journals, establishing itself as an important process to mapping knowledge, depending on boundaries, perceptions, and researcher motivations [39-42].

Thus, the main attribute of ProKnow-C is its ability to become a tool to support the construction of knowledge in a particular research field, providing a structured and rigorous

procedure that minimizes the use of randomness and subjectivity in the literature review process [43,44].

The entire process consists of four steps: Step 1: selection of a portfolio of articles on the research subject, Step 2: bibliometric analysis of the portfolio, Step 3: systemic analysis, and Step 4: definition of the research question and research objective. In this study, two stages of the process were developed: selection of a portfolio of articles on the research subject and the bibliometric portfolio analysis. Hence, part of the necessary knowledge regarding the research topic has been built.

4. Results and Discussion

4.1. Selection of the Bibliographic Portfolio

The sub-process of selecting the portfolio of articles is the initial step in the process and allows the researcher to select the articles related to the research topic, aligned according to their perception and the imposed boundaries. This selection step is performed through three sub-steps: a) selection of articles in databases, making up the Gross Bank of Articles; b) filtration of the selected articles based on the alignment of the research; and (c) the representativeness test of the bibliographic portfolio. As a result, there is a set of papers that are considered to be relevant to the researcher and aligned with the research topic. This set of articles is called the bibliographic portfolio [45].

The selection step of the article set had 759 publications, which were included in the initial portfolio called Gross Article Bank. To gather the studies and make up the Article Bank, the *Endnote X3* application was used as a bibliographic manager. Three lines of research were defined for the method's application. The first line is related to the central theme of the study, i.e., Performance Evaluation. The second and third lines are directly related to the study topic, i.e., Costs and Ergonomics. Keywords were also defined in that step for each research line and implementation of compliance tests for the keywords. For research line 1, six keywords were defined: *Performance, Evaluation, Appraisal, Assessment, Management, and Measurement*. For research line 2, one keyword was defined: *Costs*. For research line 3, *Ergonomics*, was defined as the keyword.

Next, among the databases included in the Portal of Journals of the Coordination of Improvement of Higher Education Personnel (CAPES), we searched databases that were aligned to the knowledge areas considered to be relevant to the research, namely Health Sciences, Engineering, and Multidisciplinary areas. Initially, 12 databases were identified: *SciVerse SCOPUS, WILEY, Web of Knowledge-ISI, Pubmed, PROQUEST, EBSCO, Science Direct, Cambridge Journals Online, Emerald, IEEE Xplore, SAGE Journals Online, and Scielo*. Out of these, six databases were selected for this study: *SciVerse SCOPUS, WILEY, Web of Knowledge-ISI, Pubmed, PROQUEST, and EBSCO*, which index a set of scientific journals that are more aligned with the research topic (Fig.3). Research in these databases was conducted from March 15, 2013, to May 4, 2013.

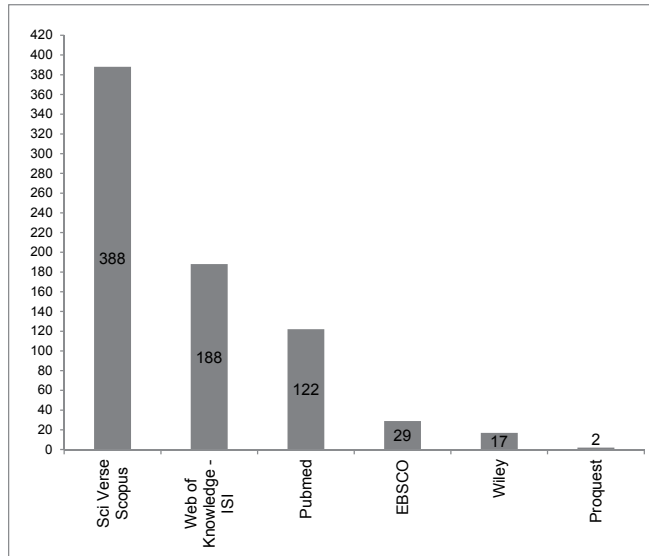


Figure 2. Number of scientific articles aligned with the research topic found in the databases.

Source: The Authors

In the second step, using the bibliographic manager, the filtration of the gross article bank, as identified in the databases, was conducted. We analyzed 759 articles, and the following aspects were considered: a) presence of repeated/redundant articles, b) alignment of article titles with the topic, c) scientific recognition of the articles, d) alignment of abstracts with the topic, and e) availability of the complete articles in the databases. After examining the articles, 14 were considered to be aligned with the research topic, and the filtering process of the articles was stopped.

Next, the test of the representativeness of the Bibliographic Library was performed to analyze the cited references in the articles from the Gross Portfolio. To achieve this, all references in the articles were surveyed, restricting the temporal space for study, from 2000 to 2013, and to articles published in journals. Again, the bibliography manager *EndNote X3* was used for the composition of references of the bibliographic portfolio. Then, the cited articles were exported to a spreadsheet to determine the filtering and representativeness of the citations.

After the worksheet was assembled and organized, a new query was performed in *Google Scholar* to identify the number of article citations from the bibliographic portfolio. After this step, the spreadsheet was reorganized

and the content was classified by a number of citations in decreasing order, thus establishing the degree of representativeness of each article in % compared with the total number of references. Two articles were identified that included known authors, with a high number of citations, 91 and 43, respectively, and aligned with the topic, which was incorporated into the bibliographic portfolio, totaling 16 articles; 14 primary articles were from the bibliographic portfolio and 2 were selected from the representativeness test, as shown in Table 1.

Table 1
Selected Articles for the Library Portfolio of the Proknow-C Methodology

Authors	Article Title	No. of citations	Year
Robertson MM, Huang YH, O'Neill MJ, Schleifer LM	<i>Flexible workspace design and ergonomics training: Impacts on the psychosocial work environment, musculoskeletal health, and work effectiveness among knowledge workers</i>	163	2008
Hendrick HW	<i>Determining the cost-benefits of ergonomics projects and factors that lead to their success</i>	91	2003
Yeow PHP, Nath Sen R	<i>Quality, productivity, occupational health and safety, and cost effectiveness of ergonomic improvements in the test workstations of an electronic factory</i>	43	2003
Rosecrance JC, Cook TM	<i>The use of participatory action research and ergonomics in the prevention of work-related musculoskeletal disorders in the newspaper industry</i>	41	2000
Christmannson M, Medbo L, Hansson GÅ, Ohlsson K, Unge Byström J, Möller T, Forsman M.	<i>A case study of a principally new way of materials kitting - An evaluation of time consumption and physical workload</i>	36	2002
Yeow PHP, Nath Sen R	<i>Productivity and quality improvements, revenue increment, and rejection cost reduction in the manual component insertion lines through the application of ergonomics</i>	29	2006
Driessen MT, Anema JR, Proper KI, Bongers PM, Beek AJVD	<i>Participatory Ergonomics to prevent low back and neck pain among workers: Design of a randomized controlled trial to evaluate the (cost-effectiveness)</i>	2	2008
Craig BN, Congleton JJ, Kerk CJ, Amendola AA, Gaines WG	<i>Personal and non-occupational risk factors and occupational injury/illness</i>	23	2006
Herbert R, Dropkin J, Warren N, Sivin D, Doucette J, Kellogg L, Bardin J, Kass D, Zoloth S	<i>Impact of a joint labor-management ergonomics program on upper extremity musculoskeletal symptoms among garment workers</i>	22	2001
Lindegård A, Karlberg C, Wigaeus Tornqvist A, Toominga A, Hagberg M.	<i>Concordance between VDU-users' ratings of comfort and perceived exertion with experts' observations of workplace layout and working postures</i>	19	2005
Spielholz P, Davis G, Griffith J	<i>Physical risk factors and controls for musculoskeletal disorders in construction trades</i>	13	2006
Abdel-Malek K, Yu W, Yang J, Nebel K	<i>A mathematical method for ergonomic-based design: Placement</i>	12	2004
Guimarães LM, Ribeiro JLD, JS Renner	<i>Cost-benefit analysis of a socio-technical intervention in a Brazilian footwear company</i>	02	2012
Trask C, Mathiassen SE, Wahlstrom J, Heiden M, Rezagholi M	<i>Modeling costs of exposure assessment methods in industrial environments</i>	01	2012
Maldonado A, García JL, Alvarado A, Balderrama CO	<i>A hierarchical fuzzy axiomatic design methodology for ergonomic compatibility evaluation of advanced manufacturing technology</i>	00	2013
Rickards J, Putnam C	<i>A pre-intervention benefit-cost methodology to justify investments in workplace health</i>	00	2012

Source: The Authors

The next step, the bibliometric analysis of the bibliographic portfolio, consists of applying statistical methods to the selected articles, to quantify the existing information, and map the structure of knowledge of a particular scientific field [46]. Five aspects were considered in this analysis step: a) relevance of the journals, (b) recognition of scientific articles, (c) most prominent authors, (d) most used keywords, and (e) analysis of the journal impact factor of the bibliographic portfolio [47,42].

Among the 16 publications of the bibliographic portfolio, the *Applied Ergonomics* Journal is highlighted, with five publications, followed by the *International Journal of Industrial Ergonomics*, with four publications. These publications are geared toward ergonomics. The first is focused on the use of ergonomics in various sectors, including the industrial sector, and the second publication has its editorial content geared to ergonomics and its use in

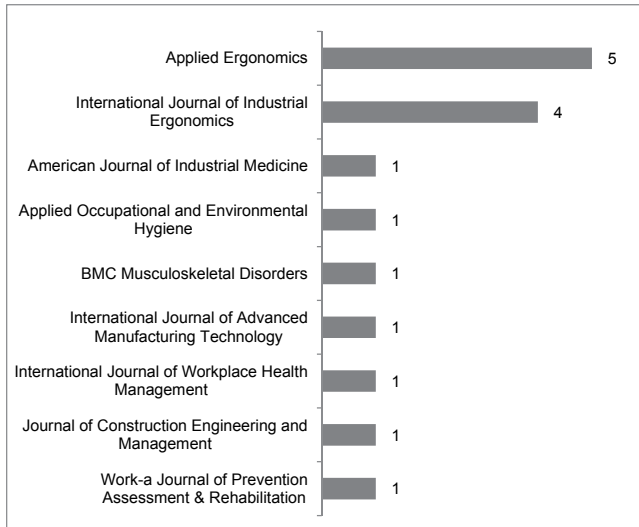


Figure 3. Number of selected articles per journal for the bibliographic portfolio of the ProKnow-C knowledge construction methodology. Source: The Authors

industry. Hence, it is fully justified that, within the research topic, many works are found in these two journals. Importantly, the bibliographic portfolio articles were published in 9 different journals (Fig. 2).

As for the scientific recognition of the Articles of the bibliographic portfolio, the most cited work was the scientific paper entitled *Flexible workspace design and ergonomics training: Impacts on the psychosocial work environment, musculoskeletal health, and work effectiveness among knowledge workers*, from the authors M. M. Robertson, Y. H. Huang, M. J. O'Neill, and L. M. Schleifer, 2008, Journal of Applied Ergonomics, with 163 citations on *Google Scholar*. The following articles have also been emphasized: *Determining the cost-benefits of ergonomics projects and factors that lead to their success*, by H. W. Hendrick (2003), with 91 citations on *Google Scholar*; Similarly, *Quality, productivity, occupational health and safety and cost effectiveness of ergonomic improvements in the test workstations of an electronic factory*, by P. H. P. Yeow and R. N. Sen (2003), with 43 citations. The authors are recognized in the scientific community by several papers in the area of ergonomics, management of its costs, and benefits of its application to various sectors of the economy, including industry, and thus aligning itself to the research topic.

Among the 61 authors of the bibliographic portfolio, Yeow and Sen are highlighted with two articles: *Quality, productivity, occupational health and safety and cost effectiveness of ergonomic improvements in the test workstations of an electronic factory* (2003), with 43 citations on *Google Scholar*, and *Productivity and quality improvements, revenue increment, and rejection cost reduction in the manual component insertion lines through the application of ergonomics* (2006), with 29 citations. In both articles, the authors write together without the participation of other authors. Both works have focused on the implementation of ergonomic improvements in workstations of the electronic components industry, and

economically measure the costs and benefits of such interventions.

As for the authors listed in the articles' references, 334 scholars were identified who contribute to the scientific community in some way. Of these, P. Vink is highlighted, with 8 papers in the references, though none is exactly aligned with the research topic. Furthermore, W. Karwowski is highlighted with 6 studies in the references.

The most relevant articles selected by this methodology emphasize aspects related to the ergonomic design of workstations and their adequacy for workers, the psychosocial work environment, musculoskeletal health, and work-related accidents. After the application of ergonomic concepts, these aspects can evolve significantly, often leading to benefits that far outweigh their implementation costs. The cited studies are characterized by the common goal of providing managers with information for comparison of the implementation costs of ergonomic measures with their financial impacts and the enhanced quality of life of the employees.

In the industrial sector, measuring the ergonomic costs and benefits derived from improved ergonomic conditions in the workplace is a difficult task. Manager resistance and the difficulty in gathering data and economic arguments to justify a financial investment in more adequate working conditions pose major obstacles to the implementation of ergonomic projects. However, the results obtained by studies prove that improved ergonomics can result in reduced musculoskeletal discomfort, tighter control of work activity, a greater sense of community, improved communication and collaboration, and efficiency in business processes. Consequently, successful ergonomic projects result in cost reduction for industrial organizations.

Conclusion

Our methodology allowed for the identification that scientific production in the field of ergonomic costs, as a criterion for evaluating and improving organizational performance in industry, is a study field that has recently received increasing attention from scholars. In agreement with the finding that it is a fairly unexplored area in terms of scientific publications, it was found that the articles in the bibliographic portfolio do not show such a high number of citations, with 68% of articles from the bibliographic portfolio in the 12–91 citation range.

Recently, the scientific production has shown a great increase, and signs point to further increases in the coming years. At the same time, when there is a larger amount and better quality of information available to the researchers, they are unable to make use of all of the available information. Therefore, it is necessary to selectively choose the content to be considered in their research. The work of establishing a selection criterion and following a rigorous process in the search for relevant information can be difficult. Thus, there is a need to use an objective methodology for selecting bibliographic references for scientific research.

This study conducted an investigation and disclosure of relevant publications about ergonomic costs as a criterion for

evaluating and improving organizational performance in industry, reported by the *ProKnow-C* intervention instrument.

Considering the limitations of the study—which are restricted to the articles published in scientific journals in the databases available on the CAPES Portal, in its entirety, based on the knowledge generated during the investigative process—we believe that the results shown may contribute to the scientific community because of the presentation of a structured process to identify and select relevant and aligned articles to the ergonomic costs theme as a criterion for evaluating and improving the organizational performance in industry, as well as the disclosure of the characteristics of the selected publications for the operationalization of the *Proknow-C* intervention instrument.

Therefore, the following points are suggested for future research: (a) replication of the process to other contexts from conference proceedings, theses, dissertations, and books, as well as searches in various available databases on the CAPES portal; and (b) continuation of this research through the development of two missing steps in *Proknow-C*: systemic analysis (content analysis of the bibliographic portfolio) and identification of opportunities for scientific research with the suggestion of research questions and objectives.

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