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PRACTICES RELATED TO INDUSTRY 4.0 AND ITS APPLICATIONS IN THE FIELD OF ERGONOMICS: ANALYSIS OF APPLICATIONS OF COLLABORATIVE ROBOTS (COBOTS) AND EXOSKELETONS

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SUMMARY: Due to the constant change in markets and means of production today, it has become necessary to optimize technologies and systems to keep up with this demand. Thus, technological companies from all over the world mobilized and began to invest in new technologies, generating a new production concept that deals with the implementation of the internet in current services and means of production, aiming to improve communication between machines, production time, aiming the policy of constant and intermittent improvements, system virtualization, reduction in product life cycle and the use of sensors in machines. As new technologies follow the above standards, this new era is called “Industry 4.0”, which is believed to be the 4th industrial revolution. Along with this new trend, questions about worker health came, making the reconciliation of Industry 4.0 technologies and Ergonomics plausible. Therefore, the objective of this study was to analyze the process of implementing technologies associated with Industry 4.0 and its applications in the field of ergonomics and discuss whether these technologies improve the production process within companies and contribute to better working conditions in the interaction of these technologies. with the work of operators, a comparison made based on a literature review. Methodological assumptions: The study had as a reference the concepts of cooperation of man-task-machine systems contained in ergonomics.

KEYWORDS: Industry 4.0; Ergonomics, Human Factors; COBOTs; Exoskeletons

INTRODUCTION

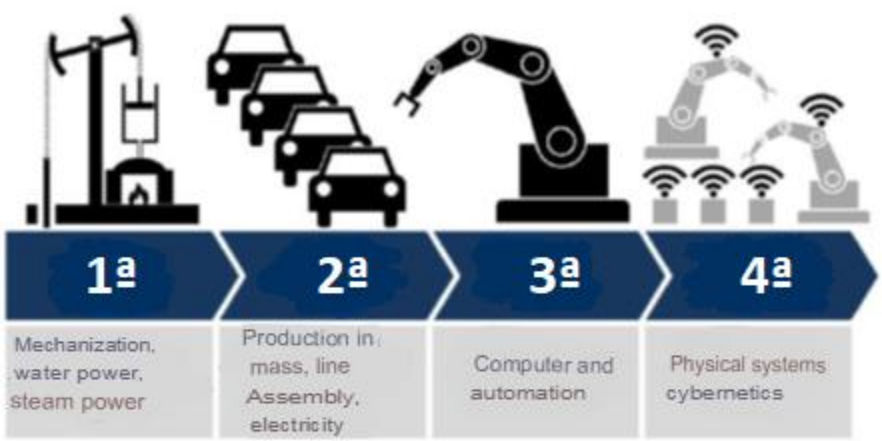
This article addresses the technologies associated with Industry 4.0 and their applications in the field of ergonomics and aims to identify practices related to Industry 4.0 and their applications and contributions in the field of ergonomics (in particular in the field of Physical Ergonomics), contributing to the systematization knowledge about these technologies and equipment. The aim is to discuss what these technologies are and whether they are effectively improving the production process within companies and contributing to better working conditions. This is the current dilemma presented by the literature, which studies phenomena of this type related to Industry 4.0 (HERČKO; ŠTEFÁNIK, 2015; MARKOVÁ et al., 2019)

Since the first industrial revolution, the world has increasingly demanded changes and adaptations from companies, organizations and the human being's own routine. In this case, the requirements are technological developments and advances in all industrial sectors, in addition to increased competitiveness, market changes and the need for new strategies to adapt to this (MARKOVÁ et al., 2019).

It was in this environment that Industry 4.0 emerged, which is a term created by the German minister of education and research, used to refer to the 4th industrial revolution. This revolution deals with the implementation of the internet in current services and means of production, aiming to improve communication between machines, production time, aiming at a policy of constant and intermittent improvements, the virtualization of systems, a reduction in the product life cycle and the use of sensors in machines (HERČKO; ŠTEFÁNIK, 2015; MARKOVÁ et al., 2019).

The first industrial revolution was the era of mechanization of the production system, the second was the era of mass production, of production lines using electricity, the third was the era of automation and the implementation of computers and the fourth, believed to be se, which is the era of cybernetic physical systems. A better visualization of these eras can be seen in Figure 1 (MARKOVÁ et al., 2019; MIKULIĆ; ŠTEFANIĆ, 2018).

Figure 1 - Summary of Industrial Revolution



Source: Roser, 2015

Within the technologies of this new industrial revolution, ergonomics approaches have emerged that aim to reconcile machine work with human beings, in order to make their work less stressful and more productive. The stress mentioned above can be both physical and mental and it is at this point that industrial ergonomics integrates knowledge of physical, cognitive and organizational ergonomics. For each of these domains there are new proposals for solutions brought by industry 4.0 and similarly there is research that studies its impacts within companies, both for the worker and for productivity (KADIR; BROBERG, 2020).

In physical ergonomics, the effects of work on the worker's musculoskeletal system are studied, unlike cognitive and organizational ergonomics, which study possibilities of reducing the mental stress of these workers (KADIR; BROBERG, 2020), in this sense, it is worth highlighting that the ergonomics integrates these domains and understands work overload as a result where the three domains play a role and influence each other.

That said, it should be noted that the present study focuses on technologies oriented towards physical ergonomics. Among the new technologies in this area, COBOTS (collaborative robots) and Exoskeletons are, according to the bibliographic review that will be presented in this study, the most studied and which presented problems related to their implementation within organizations (BANCES et al., 2020; DE LOOZE et al., 2016; WESSLÉN, 2018).

This raises important questions, such as: what are the positive and negative impacts of implementing these technologies? What are the difficulties encountered and barriers to implementation and use. How are the solutions of these technologies reconciled with the work of operators? How does the cooperation process work to adapt productivity and work safety?

To answer these questions, a bibliographical review of the implementation processes of such technologies in Brazil was carried out, the results of which will be presented and discussed in this work. This initial research helped to gather information for the generation of case studies that are under development and that will later be published in new academic articles.

The relevance of studying such technologies is due to the fact that there are gaps in the literature, mainly because it is an emerging topic, which is evidenced in the literature review presented in this article. Furthermore, it is important to highlight that these studies can support companies in the process of choosing technologies, acquisition and implementation, as well as in the search for indicators that allow improving working conditions.

METHOD

To answer the research questions presented above, a literature review was carried out to help formulate the research problem and identify technologies related to ergonomics in the context of Industry 4.0. The bibliographic review was carried out using the CAPES Portal Database (Coordination for the Improvement of Higher Education Personnel), which brings together journals from different areas of knowledge.

The following strings were used through the advanced search field: Industry 4.0, Ergonomics, COBOTs, Human Factors and Exoskeletons. The searches were carried out between 06/29/2020 and 07/15/2020 and articles published between 2013 and 2020 were selected.

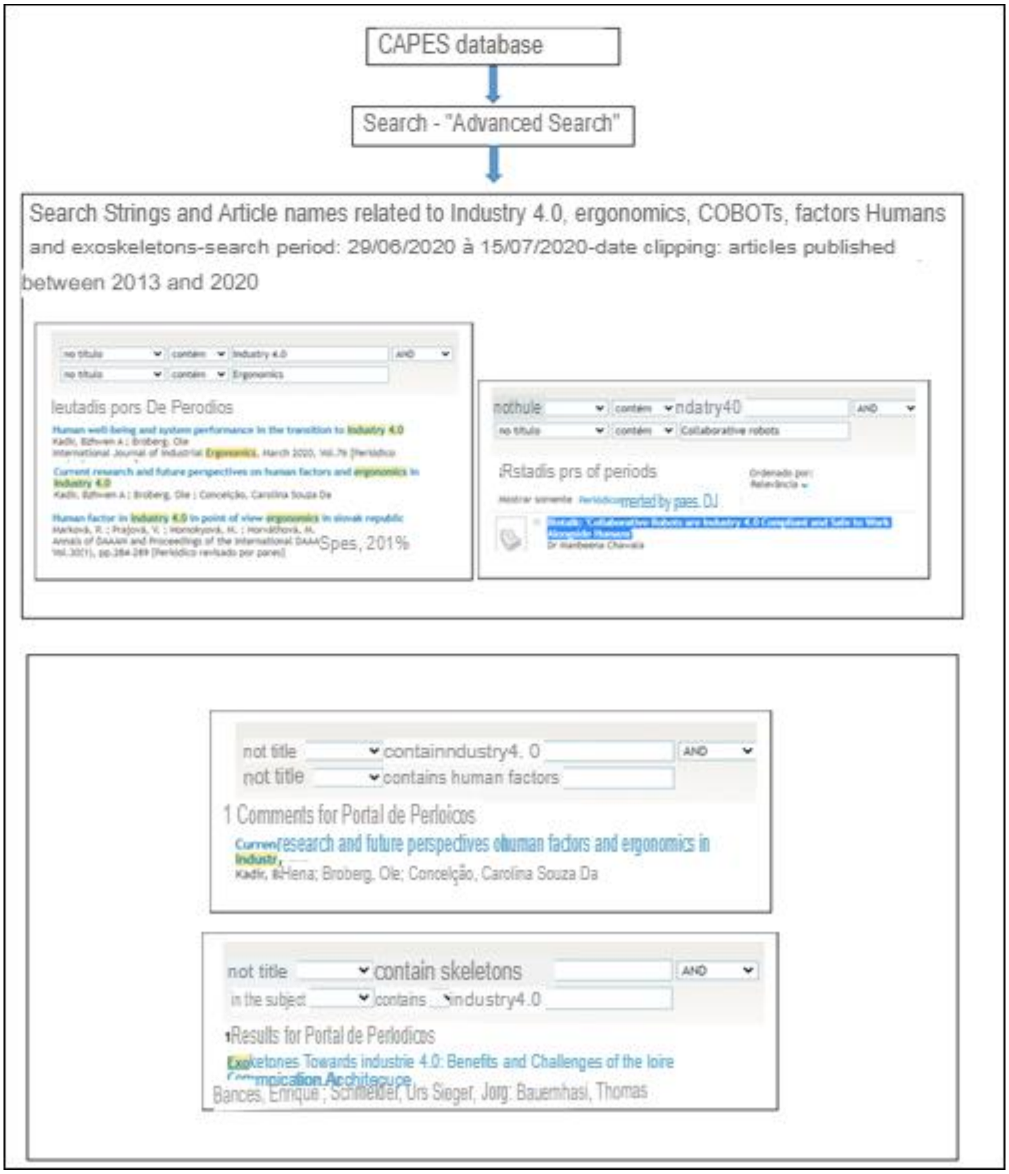
At this first moment, among 10 results found with the strings “Industry 4.0 and Ergonomics”; “Industry 4.0 and Collaborative Robots”; “Industry 4.0 and Human Factors” and “Industry 4.0 and Exoskeletons”, 6 of them made the relationship between Industry 4.0, Ergonomics, COBOTs, Human Factors and Exoskeletons.

This search, in particular the literature review, helped to define the technologies as the focus of the research: Collaborative Robots and Exoskeletons, which were identified as the main technologies associated with ergonomics.

After a systematic bibliographic review, a complementary review was carried out that provides (i) technical information about the standardization process of these technologies and also (ii) a view of how some suppliers offer their technologies. The complementary content made it possible to understand the standards related to the topic and the way in which these technologies are disseminated and how this can influence the expectations of the companies that purchase them.

Figure 2 illustrates the bibliographic review process.

Figure 2 – Illustration of the Bibliographic Review process



RESULTS

From reading the articles obtained in the systematic bibliographic review process presented above, it was possible to establish an understanding of what and how Industry 4.0 technologies are associated with ergonomics.

Firstly, it was necessary to understand, through the articles analyzed, what characterizes a technology associated with Industry 4.0, in this sense, it is understood that in Industry 4.0 there are three pillars, which are: Internet of Things and Services – IoT and IoS), Cyber-physical systems and Big Data, which are connected to each other.

Internet of Things and Services is the term used to refer to advances in internet systems, which connect more products and services than there are people on earth. In this case, it represents the impact that this new era has brought to the world, connecting different locations around the world through different technologies that expand these connection possibilities (COELHO, 2016).

Cyber-physical systems are those that interconnect computing, communication networks, embedded computers and physical processes, that is, they replace information systems, which were central computers, with a ubiquitous computing system, which makes information available anywhere. access.

Big Data, which refers to the large amount of data from these new systems that has to be stored somewhere, thus generating challenges regarding the storage and interpretation of information generated by them. This attempts to define a new technological era (COELHO, 2016).

Taking the discussion to the world of work, Kagermann (2013) believes that industry 4.0 will drastically change the work content, processes, organization and environments in factories of the future. As a consequence of this there will be an increase in the workload for all corporate members in terms of problem solving, abstraction, management complexity and physical overheads.

Thus, with the changes proposed by Industry 4.0, concerns about workers and how they will adapt to these drastic changes also arose. Therefore, with the rise of new means of production came collaborative technologies guided by wireless systems that attempt to work in cooperation with human beings, ensuring worker safety, well-being and improving the physical interaction of man with his environment. work, that is, ergonomic factors (KAGERMANN, 2013); ESBEN H. et al., 2016).

The literature, as well as the International Association of Ergonomics and Human Factors, divides these ergonomic factors into three types, which are: Physical, Cognitive and Organizational ergonomic factors and in each of these areas there are new technologies, brought by Industry 4.0, which are tested to try to prove its effectiveness, both in productivity and worker health.

In this context, focusing on the domain of physical ergonomics, Kadir and Broberg (2020) demonstrate that among the various technologies being studied in this niche, there are two of them that are the biggest focus of research, which are collaborative robots (COBOTS) and exoskeletons (KADIR; BROBERG, 2020).

Collaborative robots (COBOTS)

When we talk about COBOTs, it is an attempt to reconcile the work of humans and machines in a safe way, as they are intended to serve as a tool for workers and at the same time increase their productivity, without generating stress. physical or mental (ESBEN H. et al., 2016).

The main difference between COBOTS and conventional industrial robots is that COBOTS are supposedly safer and allow direct interaction with human beings, cooperating with their tasks. Conventional industrial robots require space segregation and for safety reasons cannot share space. space with human beings.
Figure 3 illustrates this difference.

Figure 3 – Comparison between COBOTS and Industrial Robots

Source: Cobots Image: https://elcoindustria.com.br/cobots-robos-colaborativos-linha-producao/, accessed in September. 2020. Source: Imagem Robôs Industriais: http://reparocompensa.blogspot.com/2019/01/ranking-dos-14-maiores-fabricantes.html, accessed on Sep. 2020.

Exoskeletons

Exoskeletons, which are suits that include a mechanical structure (whether or not composed of actuators), appear as an attempt to reduce musculoskeletal changes generated by repetitive work and ergonomically unfavorable positions for the worker (BANCES et al., 2020).
According to De Looze et al. (2015) and Wesslén (2018), there are two types of exoskeletons: those that are passive and do not use any type of actuator to make movements, using only materials to support a posture, or those that are active and support postures with the strength of the actuators.

Figure 4 – Comparison between Passive and Active Exoskeleton work execution

Source: Passive Exoesqueleto Image: https://economia.estadao.com.br/noticias/geral,em-fabrica-da-fiat-operarios-e-exoesqueletos,70002150839, accessed in Sep. 2020.

Results of the analysis of normative materials on Technologies

After identifying the technologies associated with Ergonomics in the context of Industry 4.0, a complementary review was carried out, initially seeking to understand the standards associated with these technologies and the regulations imposed by governments or technical standards associations on the use of these technologies, in this context, several standards on Collaborative Robots were found, however, no standards were identified regarding the use of Exoskeletons.

The necessary safety measures in the creation and construction of machines are derived from legal provisions. For machines sold in the European community, the 2006/42/EC machinery directive generally applies and in industrial environments in Brazilian territory, NR-12 applies. Both describe requirements for the design and construction of safe machines. In addition to these, the ISO 12100 standard assists in this process. The primary objective of this Standard is to provide designers with a general framework and guidance for decisions during machine development to enable them to design machines that are safe for their intended use.

The concept of machine safety considers the ability of a machine to perform its intended functions during its life cycle, where risk has been adequately reduced.

This International Standard is the basis for a set of standards that have the following structure:

- Type A standards (basic safety standards), providing basic concepts, design principles and general characteristics that can be applied to machines
- Type B standards (generic security standards) deal with security or a type of safeguard that can be used on a wide range of machines:
    - Type B1 standards address specific safety characteristics (e.g., safe distances, surface temperature, noise)
    - Type B2 standards on safeguards (e.g., two-hand controls, interlocking devices, pressure-sensitive devices, protectors)
- Type C standards (machine safety standards) that address detailed safety requirements for a particular machine or group of machines. Within this standard, ISO 10218-1 and ISO 10218-2 apply and, as a complement to them, ISO 15066

In this context, the ISO 10218-1 Robots standard – Provides guidance for ensuring safety in robot design and construction. Since safety in the application of industrial robots is influenced by the design and application of the particular robot system integration.

ISO 10218-2 Robot Systems and Integration - Provides guidelines for protecting personnel during robot integration, installation, functional testing, programming, operation, maintenance and repair.

Finally, specifically on collaborative robots, the ISO 15066: 2016 Operation of Collaborative Robots standard - provides guidance for the operation of the Collaborative Robot, which is a system that integrates the Robot and the worker in the same workspace. In such operations, the integrity of the safety-related control system is of great importance, particularly when process parameters such as speed and force are being controlled. Therefore, a comprehensive risk assessment is necessary to evaluate not only the Robot system itself, but also the environment in which it is placed, i.e. the workplace.

In Brazil, on a definitive and mandatory basis, the design and construction of machines and equipment must follow the requirements of Regulatory Standard NR-12. This standard and its annexes define technical references, fundamental principles and protective measures to safeguard the health and physical integrity of workers and establish minimum requirements for the prevention of accidents and illnesses at work in the design and use phases of machinery and equipment, and also its manufacture, import, commercialization, exhibition and transfer in any capacity. NR 12 prescribes that robotic systems that comply with the requirements of standards ABNT ISO 10218-1, ABNT ISO 10218-2, ISO/TS 15066 and other official technical standards or, in the absence or omission of these, in the applicable international standards, are in accordance with the security requirements set out in this NR, therefore, in Brazil, COBOTS must follow these ISO standards to comply with national legislation.

After reviewing the standards, the websites and promotional materials of some manufacturers were observed to understand how these technologies were disseminated and compare them with the results identified in the literature.

Results of the analysis of information materials from Manufacturers and Technology Suppliers

Informative materials made available by three manufacturers of each type of equipment were analyzed, it was decided to omit the names of the companies in this article. As expected, manufacturers highlight many benefits obtained from using this equipment and confirm the associations in their literature with Industry 4.0 and aspects linked to physical ergonomics.

i. COBOTs

Manufacturer A – The manufacturer describes its product as revolutionary and brings a modular and mobile approach to assembly on the factory floor, which allows for coping with the high complexity brought about by the increase in product variety and the continuous integration of new processes in production. These characteristics aim to increase production, quality and cost saving benefits, in addition to reducing the physical burden on the worker. On the manufacturer's website there are reports of successful implementation cases in large companies around the world.

Manufacturer B – The manufacturer promotes its product by selling the idea of a technology that contributes to a safer working environment, working in environments that humans cannot, such as dangerous or monotonous tasks for the worker, such as assembling machines, assembling boards, circuit, metal processing, injection molding, packaging, loading and unloading, as well as testing and inspection. It also provides a quieter and less stressful working environment, when compared to the environment of industrial robots. The product also has a "user-friendly" design, which, according to Manufacturer B, makes it easier for workers to accept the technology.

Manufacturer C – The manufacturer says its X-Series collaborative robots offer more options, more payload, more range and more speed than any other COBOT series on the market. They also guarantee safety certification, providing COBOTs that work side by side with humans, adding value to the processes involved with technology. Supplier C guarantees that the acquisition of technologies is the solution for small and large companies, providing quick installation, easy use and high reliability.

ii. EXOSKELETONS

Manufacturer A – This manufacturer provides an industrial exoskeleton for the upper limbs (UL), which is passive and aims to reduce efforts when carrying out activities that require the shoulders, arms and back complex, seeking to optimize productivity and reduce physical load. They claim that their product is highly technological, but it is still extremely simple to use and put on, with application times of 30 seconds. Its production is entirely Brazilian, and therefore the cost and maintenance of the equipment are cheaper compared to imported products, withstanding up to 600 thousand cycles, simulating use in a 24 hour x 7 day environment, with 3 shifts for 1 year without maintenance . Among the characteristics of the equipment, its weight stands out, the reduction of strength in the arms that the equipment allows, freedom of movement for shoulders and arms, there are connected versions (IoT) for monitoring the use and maintenance of equipment and data monitoring (arm angle, hours of use per user, equipment hour meter).

It is observed that, although the manufacturer is associated with industry 4.0 technologies, this is the only characteristic that is associated with the tripod identified based on 4.0 technologies.

Manufacturer B – This manufacturer provides an Industrial Exoskeleton for upper limbs (MMSS), which is passive and aims to make the worker the center of the production process, thus aiming for more modern, efficient and productive factories. It claims that its product preserves and enhances the worker's capabilities by reducing physical loads, such as overload and Repetitive Strain Injuries (RSIs). This technology adjusts to different body structures, providing daily support to the worker and bringing comfort, which consequently increases the quality, efficiency and consistency of repetitive work performed. Manufacturer B's website provides a brochure for their product and in it they report an average reduction of 30% in muscular fatigue in the shoulder extension movement, as all effort is dissipated by the points of contact with the body and the torque boxes that transform energy potential in torque to reduce load.

Manufacturer C – This Manufacturer provides a passive Industrial Lower Limb Exoskeleton (MMII) and claims that its product is the new chair without a chair, where the worker can carry out their activities and tasks safely, reducing the stress on the lumbar spine of those who perform them. . The product allows a quick, easy and flexible change between sitting, standing and walking postures, which does not create obstacles in the execution of tasks for workers. Furthermore, the manufacturer guarantees that the Exoskeleton allows the replacement of chairs with this versatile mechanism, allows dressing in less than 30 seconds, reduces costs due to worker absence and maintains productivity, but in a more comfortable way. The difference between this manufacturer and the others studied is that, on their website, they present a proposal for implementing their product within the companies that purchased it. In this way, it proposes a standard implementation process with the assistance of a specialized team, in order to understand the functioning and needs of each client.

Final Considerations About the Results

The results demonstrate that both technologies are seen, in the literature and in information from suppliers, as contributions from industry 4.0 associated with aspects of physical ergonomics. It is clear that there are standards for collaborative robots, however, standards related to exoskeletons have not yet been identified. and its applications. Next, some discussion points and final considerations will be presented.

DISCUSSION AND FINAL CONSIDERATIONS

This article addressed the technologies associated with Industry 4.0 and their applications in the field of ergonomics and aimed to identify practices related to Industry 4.0 and their applications and contributions in the field of ergonomics (in particular in the field of Physical

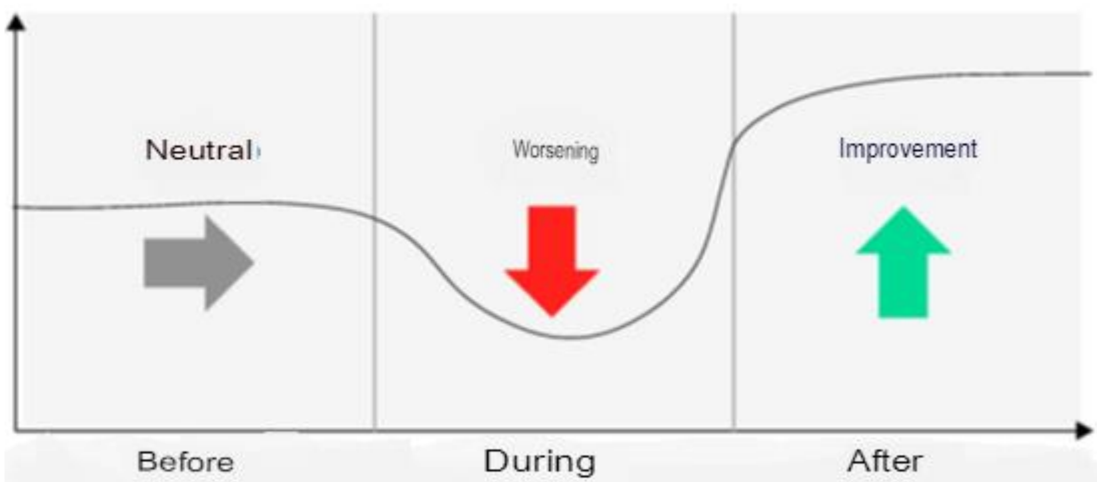
Ergonomics), contributing to the systematization knowledge about COBOTs and Exoskeletons, these objectives were developed and presented as results of the literature review.

Furthermore, it is necessary to discuss whether these are effectively improving the production process within companies and contributing to better working conditions.

In this sense, it was also verified in the literature studied, that these technological developments, which were intended to bring ergonomic improvements, came with implementation problems, difficulties in adapting workers to the new technology, lack of motivation due to there not being a standard of implementation process, resulting from the lack of studies of the new technology, and the emergence of a heavy work environment, with workers constantly worried about their jobs (KADIR; BROBERG, 2020).

According to the study by Kadir and Broberg (2020), implementation tests of these technologies were carried out in several companies of different sizes and types of production, and this implementation was divided into the “Before”, “During” and “After” phases. As a result, implementation in the “Before” and “During” periods proved difficult, as not much was known about the technology (both by the company and employees), and the implementation protocol was not yet clear and defined, causing a lot of uncertainty within companies. This gave rise to an inhospitable work environment that proved to be worse than the period before technology. After some time of study and increased clarity about these, the beneficial factors came to light and the work environment recovered its well-being, in addition to showing that the new technologies were being beneficial in a physical way (figure 5).

Figure 5 – Perceived well-being and general system performance in the periods before, during and after the implementation of new technologies



A simple overview of how perceived well-being and overall system performance change before, during and after implementing new digital technologies

Source: Kadir & Broberg, 2020

However, although improvements were noted in the "After" period in the production process and in the well-being of employees, this conclusion should not be generalized, as other factors such as the duration of implementation time, costs and the best type of technology still need to be determined. studied in more depth in order to compare benefits and harms, and therefore more focus should be placed on these processes, to shed light on a gap in the literature.

Another important discussion that emerged from this study was the classification of technologies as 4.0, for example, to what extent is a passive exoskeleton 4.0, given that very little or none of the pillars are applied in this equipment? It appears that this association is not merely commercial and that even in academic research this situation occurs, that is, reflection on the real framing of a technology in a context is not being effectively carried out.

The present study provided support for the understanding and systematization of knowledge about these technologies and will serve as a basis for new studies, which may involve real use cases, where companies that have applied these technologies are approached and invited to reflect on the positive and negative points of the use of this equipment, as well as the motivation for purchasing it and satisfaction with it.

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