



MACROERGONOMICS: AN ANALYSIS OF THE DEFINITION BASED ON THE LITERATURE

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Abstract

The text addresses the evolution of the concept of ergonomics, from its initial definition in 2000 by the International Ergonomics Association (IEA), to the development of macroergonomics. Initially, ergonomics was subdivided into three domains: physical, cognitive and organizational. However, in 2020, the IEA revised this approach, emphasizing that ergonomics does not have specific domains, but rather a holistic approach that considers several factors, such as physical, cognitive, organizational and sociotechnical.

The research carried out involved a bibliographic review, analysis of articles and classification of macroergonomics concepts into three constructs: approach, basis or consideration, and objectives and results. The results revealed that macroergonomics addresses the sociotechnical system as a whole, considering organizational, social, cultural aspects, among others. Its objectives include the design and optimization of organizations and work systems, aiming at improving organizational performance and human well-being.

Furthermore, the research highlights important authors and publications in the area, highlighting the evolution of the concept over time. It is concluded that macroergonomics is an approach to ergonomics that seeks to optimize the performance of the system as a whole, integrating human and organizational aspects. The text also pays tribute to the contribution of Lia B. de M. Guimarães to the development of the research.

Keywords: Macroergonomics; Review; Definition.

1. INTRODUCTION

In August 2000, the International Ergonomics Association (IEA) defined Ergonomics (or Human Factors) as the scientific discipline that is dedicated to the knowledge of the interactions between human beings and other elements of a system, and the profession that applies theories, principles, data and methods to projects in order to optimize human well-being and the overall performance of the system (IEA, 2020). This same definition was adopted by

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the Brazilian Association of Ergonomics (ABERGO, 2020). Ergonomics seeks, based on the analysis of physical, cognitive and organizational factors, to reduce the harmful consequences of work on the worker and increase the satisfaction and health of those involved in the work system (IIDA and GUIMARÃES, 2016).

Also in 2000, the IEA and ABERGO proposed that Ergonomics operates in three domains of specialization: Physical Ergonomics, which studies characteristics related to anatomy, physiology, anthropometry and biomechanics linked to physical activities; Cognitive Ergonomics, focusing on the mental processes of work, and Organizational Ergonomics, which translates into the optimization of sociotechnical systems, including the organizational system, policies, and processes (IEA, 2020). However, focusing on just one area of expertise is not always able to generate improvements in performance and well-being. An example of this fact is the research by Galvão *et al.* (2012), in which the approach focused on physical and cognitive ergonomics was not able to improve either health or performance indicators.

In March 2020, the IEA no longer considered these three domains of specialization and stressed that Ergonomics does not have specific domains, as the issues that are addressed are systemic. This classification, therefore, should not be used in isolation in practical applications. The approach must be holistic, considering physical, cognitive, sociotechnical, organizational, environmental factors, among others (IEA, 2020). This new understanding is in line with the broader approach to ergonomics, or macroergonomics, which considers cultural, organizational, work process issues, among other factors, with a focus on the production system as a whole (IIDA and GUIMARÃES, 2016).

The objective of macroergonomics is to optimize the functioning of every system, by analyzing the interfaces between the human being and: organization, technology, environment and people (GUIMARÃES, 2010). Authors such as Hendrick (1996; 2003), Guimarães (2012), Bitencourt (2003), Kleiner (2008) and Derenevich (2017) argue that, with macroergonomics, an increase in organizational performance is achieved, by contributing directly and indirectly to the reduction of waste.

Despite the contribution that macroergonomics can offer, not only to people's well-being, but also to the performance of the system, the approach is little used and understood, and different definitions of macroergonomics have been found. Thus, this research aimed to review the definitions of macroergonomics found in the literature to better understand the concept and elaborate its aspects within the following constructs: A) Approach, B) Basis or Consideration and C) Objectives and Results.



To this end, this research was structured in the following stages: 1) Review of published articles that mention macroergonomics; 2) Outline of the definition of macroergonomics and framing in constructs; 3) Qualitative and quantitative analysis of the definitions found; and 4) Establish a definition of what macroergonomics is, based on the study.

2. DEVELOPMENT

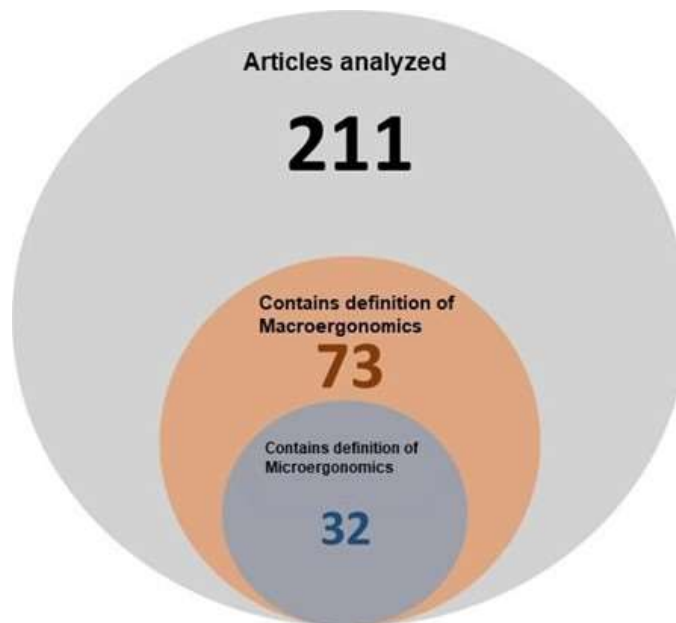
As described in the methodological procedures, in step 1, a review of published articles that mention macroergonomics was carried out. The search was carried out between December 2018 and March 2019, and updated in January 2020, on the journal platform of the Coordination for the Improvement of Higher Education Personnel (CAPES) as a primary source. As the platform had more than 45 thousand full-text titles from 130 reference databases, articles in English and peer-reviewed were initially selected. So, duplicate articles and those that were not related to the topic were excluded. Relevant references that appeared from the initial search and articles from the authors' personal library, which fit the initial search criteria, were also inserted.

For the search terms strategy, the end of all forms of writing the term "macroergonomics" in English was changed, namely: "macroergonomics", "macro ergonomics" and "macro-ergonomics" to "macroergon*", "macro ergon*" and "macro-ergon*". A result of 539 articles was obtained. The filters were then applied: articles, in English, without time restriction and peer-reviewed articles, which caused the number of results to drop to 190. Of these, three were duplicates.

With the individual analysis of the articles, 18 more publications that were not articles or were not in English and articles that were not related to the theme were removed. In addition, 42 articles were added to the search, based on references in the visited articles and the authors' personal library. Thus, the search resulted in a scope with 211 articles, of which only 73 contained a partial or full definition of macroergonomics and 32 contained a partial or full definition of microergonomics, in the perception of Derenevich (2020) (Figure 1).



Figure 1 - Representation of the total number of articles studied



Source: Derenevich, 2020.

A survey was carried out on the concepts and characteristics of what is meant by macroergonomics, what aspects the macroergonomic approach should contain, what is the relationship with organizational ergonomics and who are the reference authors for each definition. To this end, the Adobe Reader® search tool was used to search for the terms "macro" and "micro" in the texts and articles that had the image format were read in full to find the terms. Consequently, the excerpts described by the authors as macroergonomics were identified.

Then, a descriptive analysis was performed with data from the total scope, of 211 articles, containing publications per year, main authors, main places of publication, etc. From the tabulation for the 73 that contained the definition of ergonomics, the excerpts that contained characteristics of macroergonomics were recorded, and the authors referenced in the definitions. Then, for step 2, the excerpts from the articles that defined macroergonomics were tabulated and classified into constructs.

Construct A, called "Approach", categorizes how macroergonomics is applied and what aspects it uses to approach the system. For construct B, called "Base or Consideration", what is supported in theory and what refers to macroergonomics are classified. For construct C, called "Objectives and Results", what is expected to be achieved from the macroergonomic approach is characterized. In short, we sought to answer "What?", "How?" and "What for?".



In stage 3, a qualitative and quantitative analysis of the definitions found was carried out, based on: tabulation of the results in relation to the total number of articles published by authors and co-authors, and the total number of their citations; sketch of a timeline with macroergonomics milestones and grouping of similar definitions, from the point of view of Derenevich (2020). In step 4, a definition of what macroergonomics is in each construct was established, based on the results of the previous steps.

3. RESULTS AND DISCUSSIONS

The first article with the name "macroergonomics" appears in 1985, written by Hal Hendrick, who understands it as the fourth phase of the historical evolution of ergonomics, and the subdiscipline that deals with the technology of the human-organization interface and is a way to increase the overall performance of the system (HENDRICK, 1985).

Since then, macroergonomics has undergone changes in its understanding and application. In this context, and based on the scope of the research, the authors of the articles were ranked according to the total number of publications they have within their own scope, as shown in table 1. Table 2 presents the ranking considering only the main author.

Table 1 - Publication ranking by authors and co-authors

Author and Co-author	Total Articles Published
CARAYON, P	12
AZADEH, A.	9
KUMAR, R.	6
HENDRICK, Hal W.	5
KLEINER, B. M.	5
SMITH, Michael J.	5
GENAIDY, A.	4
GUIMARÃES, L. B. de M.	4
KARWOWSKI, W.	4
AMELLA, T.K.	3
BERGSTRÖM, Johan	3
CLEGG, C. W.	3
GAEINI, Z.	3
HOONAKKER, P. L. T.	3
REALYVÁSQUEZ, Arturo	3
SAURIN, T. A.	3
WILSON, John R.	3

Source: Derenevich, 2020.



Table 2 - Publication ranking - main author

Lead author	Total Articles Published
AZADEH, A.	7
CARAYON, P.	7
HENDRICK, Hal W.	4
REALYVÁSQUEZ, A.	3
AMELLA, T.K.	2
BERGSTRÖM, Johan	2
DRURY, Colin G.	2
GENAIDY, Ash	2
HIGNETT, S.	2
KLEINER, Brian M.	2
TAVEIRA, A. D.	2

Source: Derenevich, 2020.

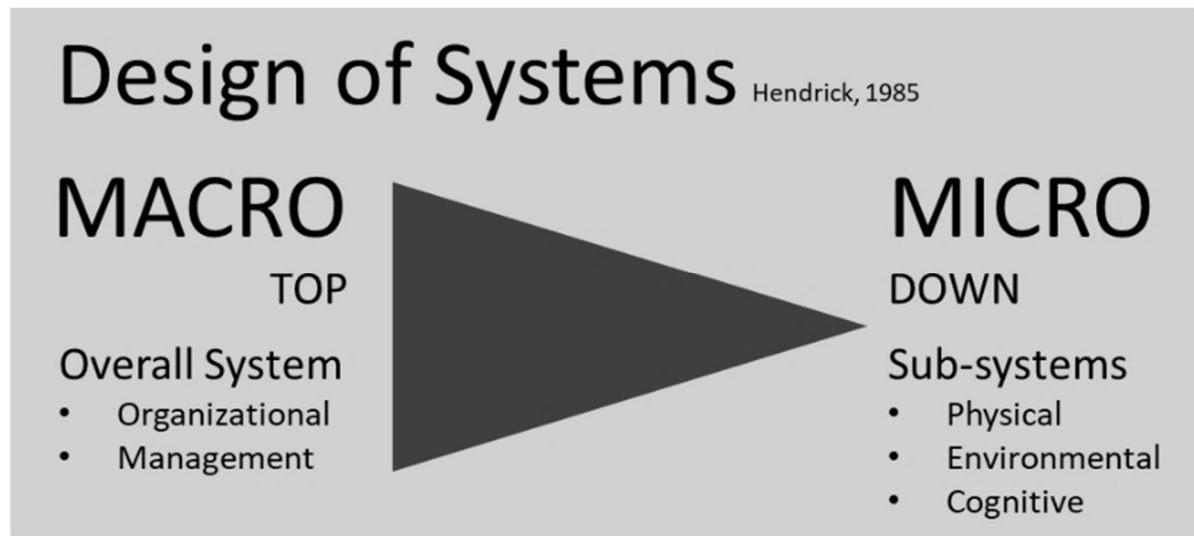
It should be noted that, although HENDRICK, H. is known as the father of Ergonomics, the authors CARAYON, P., AZADEH, A. and KUMAR, R. are the ones who stood out the most in the ranking of authors and co-authors, with 12, 9 and 6 articles published in total, respectively – which is understandable by the death of Hal Hendrick in 2011. It is worth noting that, in Brazil, the only author in the ranking is GUIMARÃES, L. B. de M., and she is co-author of four articles. In the ranking of main authors, HENDRICK, H. continues to lag behind CARAYON, P. and AZADEH, A. It is important to highlight that researchers such as HENDRICK, H. and GUIMARÃES, L. B. de M. already used the macro approach in their ergonomics work, without a concrete definition yet.

As Hendrick's contribution was notorious, since he brought the term macroergonomia, a visual representation of its definition was made (Figure 2). According to the author, this subdiscipline is responsible for dealing with human-organization interface technologies, analyzing from the "*top*" to the "*down*", that is, from the whole system to its subsystems, while microergonomics is not so comprehensive. As Derenevich (2020) cites in his work:

"Macroergonomics is differentiated by its macro character, by approaching the organization and the system as a whole, in a "systematic and progressive" way. According to Hendrick (2002), macroergonomics takes two years to be fully incorporated into an organization. This occurs exactly because of this characteristic, as it is necessary to solve the issues step by step, but gradually and constantly. On the other hand, its results appear before this date, taking between 6 and 24 months to perceive improvements in the system (HENDRICK, 2008)."



Figure 2 - Representation of the definition of macroergonomics in Hendrick's view



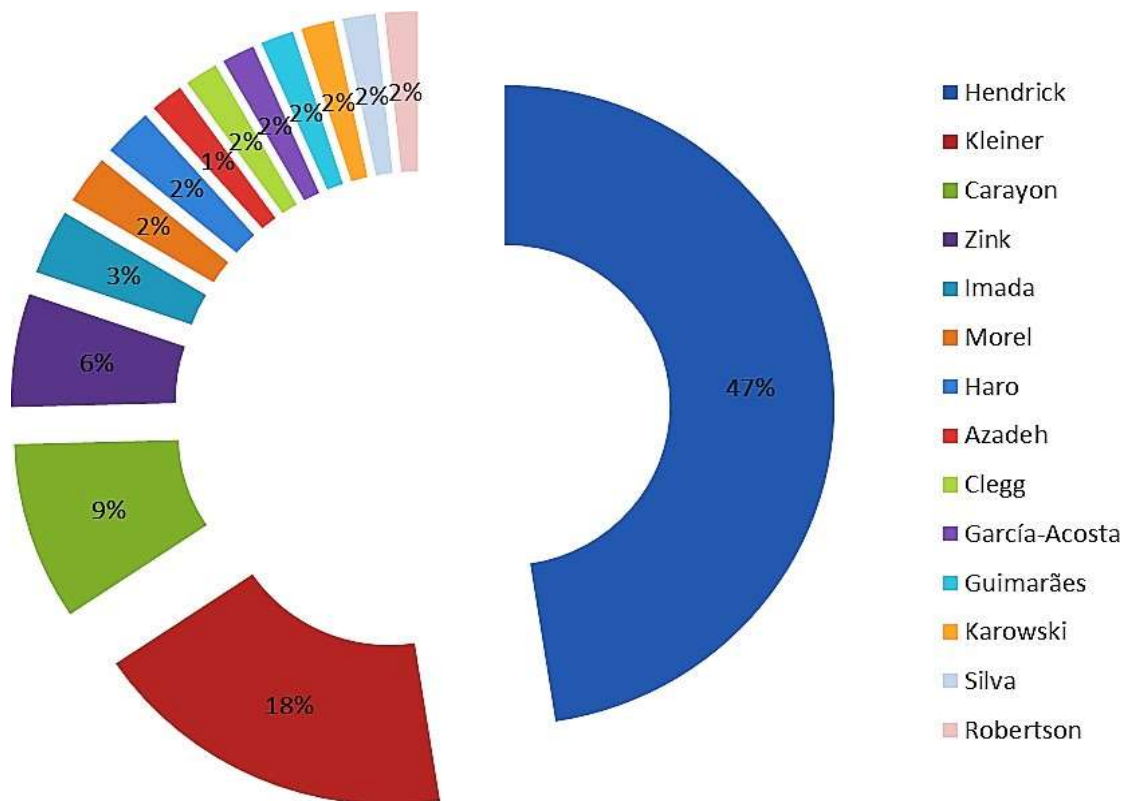
Source: Derenevich, 2020.

In addition, the 73 articles that contained some definition of macroergonomics were analyzed and read in full. Then, these data were tabulated and categorized with the respective authors and the number of observations of the references cited for the definition of ergonomics. From this, the visual representation of the citation grouping was made, as can be seen in figure 3.

It is clear that Hendrick stands out, in addition to being a pioneer, a reference in macroergonomics, as well as other authors of the sequence: Kleiner, Carayon, Zink, Imada, among others. The most cited definition of macroergonomics is that of the publication by Hendrick and Kleiner (2001), with 62 references, followed by the publications of Hendrick (1995, 1997, 2002) and Carayon (2006).



Figure 3- Main Macroergonomics References



Source: Derenevich, 2020.

A timeline was then made that presents the milestones, separated every five years. This timeline, presented in figure 4, also highlights the appearance of terms within the history of macroergonomics, understood as important in its evolution process. It is worth mentioning that the development of this timeline was not limited to articles only, as it was based on several relevant publications.

Figure 4 – Macroergonomics milestones according to the authors



1985	<ul style="list-style-type: none"> ➤ Primeira definição de Macroergonomia (HENDRICK, 1985).
1990	<ul style="list-style-type: none"> ➤ Design e Gestão Organizacional - ODAM (HENDRICK, 1993); ➤ Design Organizacional e Novas Tecnologias (BROWN, 1994); ➤ Otimização do Sistema Organizacional e de trabalho.
1995	<ul style="list-style-type: none"> ➤ Ergonomia Participativa (HENDRICK, 1995; INGELGARD, 1996; NAGAMACHI, 1995); ➤ Análise de Custo de Intervenções Ergonômicas (HENDRICK, 1996); ➤ TQM e Ergonomia (DRURY, 1996).
2000	<ul style="list-style-type: none"> ➤ Ergonomia Organizacional e Social; ➤ Conceitos preventivos e integrativos (ZINK, 2000); ➤ Top-down, middle-out and bottom-up (HENDRICK, 2001); ➤ Mudanças tecnológicas e organizacionais (ROBERTSON, 2001); ➤ Análise de Macroergonomia e Design - MEAD (HENDRICK e KLEINER, 2002); ➤ Alocação de trabalho (WATERSON, GREY & CLEGG, 2002).
2005	<ul style="list-style-type: none"> ➤ Adaptação contínua e melhoria de sistemas sócio-técnicos (CARAYON, 2006); ➤ Melhorias Sociais (RIZNANTO e PUJASAKTI, 2007; STRASSER e ZINK, 2007); ➤ Ergonomia (micro e macro) é potencialmente mais efetiva em países desenvolvidos industrialmente (IDCs) (SCOTT, 2008); ➤ Sistemas de Segurança (HARO & KLEINER, 2008); ➤ Abordagem Lean em processos Ergonômicos (EP) (HELLER-ONO, 2009).
2010	<ul style="list-style-type: none"> ➤ Performance social e econômica (THUN, LEHR & BIERWIRTH, 2011); ➤ “É mais fácil envolver os trabalhadores do que a equipe gerencial” (Guimarães <i>et al.</i>, 2012); ➤ Mapas cognitivos confusos – FCM (ASADZADEH <i>et al.</i>, 2013); ➤ Índice de Estresse Relativo (RSI) (KAZEMI <i>et al.</i>, 2014); ➤ Mesoergonomia (KARSH, WATERSON & HOLDEN, 2014); ➤ Satisfação com o trabalho (HABIBI <i>et al.</i>, 2014); ➤ “A macroergonomia é limitada pela falta de mecanismos específicos através dos quais o sistema dispersa a responsabilidade da segurança em diferentes subsistemas” (MURPHY, ROBERTSON & CARAYON, 2013); ➤ Iniciativa de Engenharia de Sistemas para Segurança do Paciente (SEIPS) (CARAYON <i>et al.</i>, 2014).
2015	<ul style="list-style-type: none"> ➤ Clima de segurança (SCHWATKA <i>et al.</i>, 2016); ➤ Combinação de atividades centradas na Ergonomia para a melhoria de ações (BOLIS e SZNELWAR, 2016); ➤ <i>Green Ergonomics</i> – Sistemas sócio-ecológicos – “Intervenções sustentáveis que focam em comunidades como um todo, respeitando subsistemas ecológicos, socioeconômicos, legais e políticos” (POON, HERATH e SARKER, 2016); ➤ Macroergonomia e fatores de Engenharia de Resiliência Integrada para tomada de decisões (AZADEH <i>et al.</i>, 2016); ➤ Análise macroergonômica e de design de métodos através de métodos matemáticos de <i>supply chain</i> (AZADEH <i>et al.</i>, 2016); ➤ Questionário de Compatibilidade Macroergonômico (MCQ) (VARGAS e ALCARAZ, 2016); ➤ Uso de Indicadores de Performance Chave (KPI) (KARIM, PARTIWI e SUDIARNO, 2018); ➤ Mede a compatibilidade macroergonômica entre subsistemas (MCQ) e sugere o desenvolvimento de análises macroergonômicas e seus resultados práticos (REALYVASQUEZ <i>et al.</i>, 2018); ➤ Modelo Macroergonômico para espaços de trabalho compartilhados (KEKKONE e REIMAN, 2019)
2020	Atual

Source: The authors (2022)



It is noted that, since the first definition of macroergonomics given by Hendrick (1985), the volume of contributions to this area has gradually increased. With this, essential terms for the construction of its definition emerged. This evolution also indicates a need to delimit the characteristics of macroergonomics. In this context, and following the stages of the research, these aspects were classified into the constructs Approach, Base or consideration and Results.

A) Approach

The characteristics and aspects most cited were tabulated, as shown in Table 3. In total, 12 approaches stood out and were considered as the ones that most represent the aspects that macroergonomics uses to approach the system. Of these, the "Top-down", proposed by Hendrick, was the most cited feature, followed by the "Participatory Ergonomics", proposed by Brown.

Table 3 - Characteristics of macroergonomics

Approach	Total
Top-Down	19
Participatory Ergonomics	13
Organizational scale	4
Bottom-up	4
Multidimensional and interdisciplinary perspective	4
Human-system interface	2
Middle-out	2
Ergonomic Work Intervention and Analysis	2
Organizational Design and System Technologies	2
Systematic and progressive	1
Qualiquantitative	1
Structure, methods and processes of the Sociotechnical System	1
Analysis and Evaluation of Work Systems	1

Source: Derenevich, 2020.

A) Basis or Consideration

The Base construct or consideration reveals which are the "pillars" that support the theory of a macro approach, as well as what is the minimum that needs to be evaluated in this case. Table 4 shows the tabulation of the definitions of this construct.

It is observed that more than half of the scope of articles (58.9%) considers the sociotechnical system as a basis for macroergonomics. It is also noteworthy that there are different interpretations for sociotechnical systems, some of which are composed of the human being, organization, environment and machines; and in others by the personnel, technological and external environment subsystems. The consideration of the system as a whole and the organization in an integral way are also frequently observed in the literature.



Based on these results, macroergonomics is revealed as a way to integrate aspects of culture and the external part of the organization with internal performance and performance issues.

Table 4 - Definition of Basis or Considerations for macroergonomics

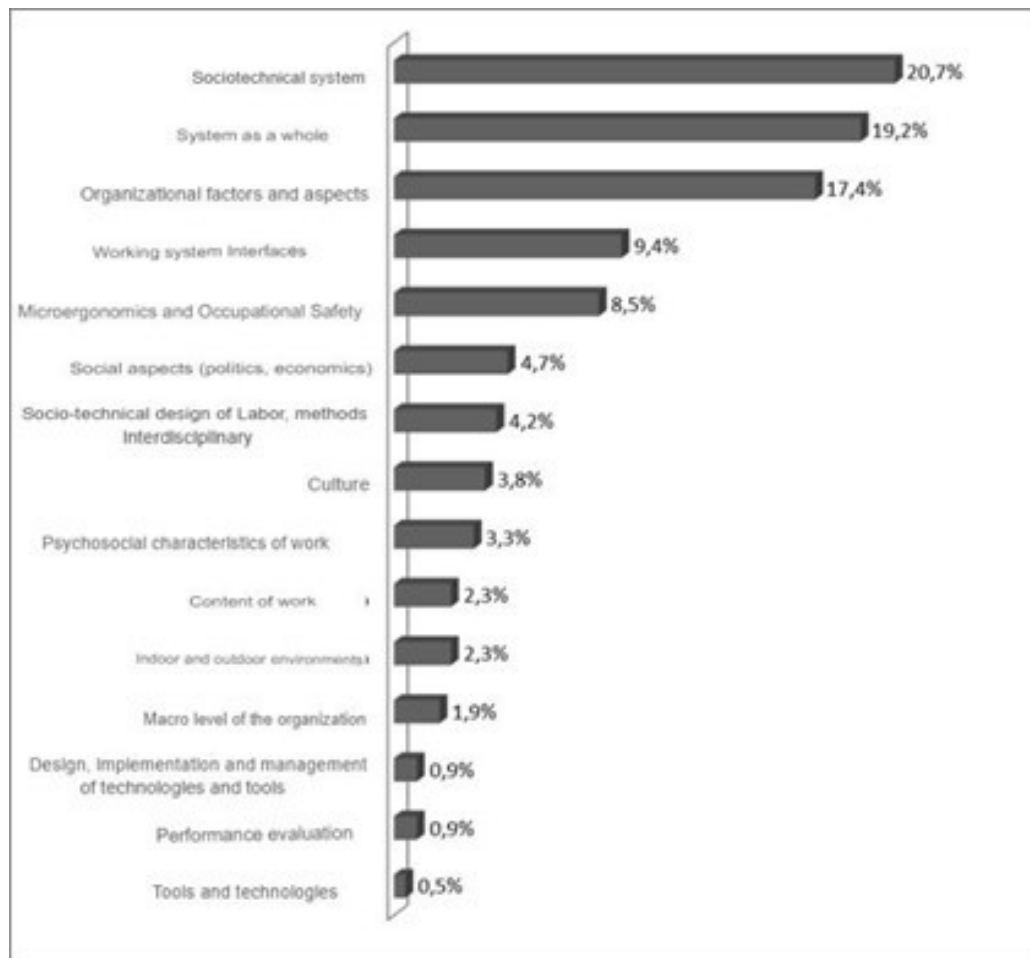
Basis or Considerations	Total
Socio-technical system (human, organization, environment and machines/personnel, technological and external environment)	44
System as a whole (individual, tasks, technologies and tools, organizational environment and conditions)	41
Organizational factors and aspects (tasks and control of work, organizational climate, leadership style, processes and structure, feedback)	37
Interfaces of the work system (human-work interaction, machine, software, hardware, technology, organization)	20
Microergonomics and Occupational Safety (physical characteristics, health and well-being)	18
Social aspects (politics, economics)	10
Socio-technical project of work, interdisciplinary methods	9
Culture	8
Psychosocial characteristics of work	7
Indoor and outdoor environments	5
Content of the work (variety, challenges, cognitive demand, achievement, overload)	5
Macro level of the organization	4
Performance evaluation	2
Design, implementation, and management of technologies and tools	2
Tools and technologies	1

Source: Derenevich, 2020.

Next, figure 5 shows the percentage representation of the definitions found above. It is noted, then, that the socio-technical system, the view of the system as a whole, and organizational factors and aspects represent, together, approximately half of all the aspects cited as a basis for macroergonomics. It is worth mentioning that, although important, performance evaluation is one of the least reported as necessary in macroergonomics. In addition, none of the publications studied cited most or all of the terms of the Base set or considerations for macroergonomics.



Figure 5 - Percentage representation of bases or considerations in Macroergonomics



Source: The authors, 2022.

A) Objectives and Results

The objectives and expected outcomes of macroergonomic interventions fall into two categories: human-oriented and system-oriented. However, although macroergonomics is seen and defined as a provider of system performance improvements, the authors do not always discuss these results. Therefore, this construct was the one that presented the lowest number of citations when compared to the others.

Regarding the human-oriented objectives, it is noted that what is most mentioned as the main benefit is the worker's better sense of security, health and quality of life (Table 5)



Table 5 - Objectives and results of macroergonomics for the human being

Objectives and Results for the Human Being	Total
Improves worker safety, health and quality of life	7
Optimizes Human Performance (effective learning environment)	6
Improves employee training and satisfaction and reduces absenteeism	4
Reduces musculoskeletal disorders	3
Reduces human cost (injuries and diseases)	1
Encourages investment in human capital	1

Source: Derenevich, 2020.

As for the system-oriented objectives, it was noticed that the most cited is the Project of Work Organizations and Systems, which is the structuring of the way the system's interfaces talk to each other (Table 6). It is noteworthy that the authors cited 3.2 times more the results and objectives for the system than for the human being, evidencing the idea that macroergonomics is concerned with the system in general.

Table 6 - Objectives and results of macroergonomics for the system

Objectives and Results for the System	Total
Project/Design of Organizations and Work Systems	27
Organizational Performance Optimization	13
Harmonization of the Work System at the macro and micro levels	8
Improvement of the System as a whole	7
Increases Productivity	7
Acts as Work Processes	5
Establishes positive organizational synergy	3
Maintenance and quality of equipment	3
Improves the physical environment	3
Preventive	2
Contributes to global societal issues	1
Integrator	1

Source: Derenevich, 2020.

Based on these results, it is possible to establish a definition of macroergonomics, as shown in Table 7. Regarding its objectives, macroergonomics aims to: I) The design and optimization of organizations and work systems; II) The quality of processes, harmonization, integration and synergy of systems/organizations; III) The integration between subsystems and the reduction of human costs in improving the physical and organizational environment.

Table 7 - Definition of ergonomics *versus* macroergonomics

	Ergonomics	Macroergonomics
Approach	-	<i>Top-down, bottom-up, middle</i> , interdisciplinary and participatory, systematic and progressive, qualitative-quantitative.
Considers	Interface between human and system elements	Interface between socio-technical system, subsystems, with the internal and external environment, social, cultural, organizational characteristics, content and safety of work, and microergonomics.
Human Results	Welfare	Increased performance, well-being, safety and quality of life, and job satisfaction
System Results	Performance	Gain in performance, harmonization and integration of the socio-technical system at macro and micro levels.

Source: Derenevich, 2020.

To achieve these objectives, it is essential to consider the socio-technical system, its interfaces, characteristics, technologies, culture, social, psychosocial and organizational aspects, internal and external environments, microergonomics and occupational safety. With this, it can be said that macroergonomics visualizes the system as a whole.

Therefore, for the authors, based on the present review, it is defined that macroergonomics should address the socio-technical system, its subsystems, the internal and external environment, the social, cultural, organizational characteristics of content and work safety, with *top-down, bottom-up, middle-out* analyses, in an interdisciplinary, multidimensional, systematic, progressive, qualitative-quantitative and participatory way. In this way, this is a means to achieve human well-being and increase performance, safety, quality of life and job satisfaction.

The importance of macroergonomics for the optimization of companies is also highlighted from the improvement of the work system design, which integrates and harmonizes from the macro level (human-organization interface) to the micro (human-machine, human-environment and human-software interfaces). The results of this are given by significant improvements in organizational performance, such as: productivity, efficiency, reliability, quality, etc., in addition to being crucial for the economic and social dimensions of sustainability.



4. CONCLUSIONS

Recent changes in ergonomics definitions, published by national and international associations, bring attention to the importance of the macroergonomic approach for today. In view of this scenario, this article aimed to review the definitions of macroergonomics and their respective classification by constructs, in addition to displaying a timeline with highlights in this evolution. As a result, 211 articles were selected from a total of 654 publications related to the theme. The terms of macroergonomics description were highlighted and used for a descriptive analysis. With the selection criteria reinforcing the presence of a definition of macroergonomics, 73 articles were selected.

Some authors such as Moral and Kragt (1990), Hignet and Wilson (2004), Karsh, Waterson and Holden (2014) understand that microergonomics considers physical or cognitive issues, and macroergonomics is focused on issues of the macro-environment. The definition of macroergonomics by Hendrick and Kleiner (2001) is the most cited (47% of the time), followed by Hendrick (1995, 1997, 2002) (18%) and Carayon (2006) (9%), these being the reference authors for macroergonomics.

The definitions were grouped into the constructs: approach, concept or base, and objectives and results for the human being and the system. Thus, the main terms found to define macroergonomics were "Participatory ergonomics" and "Top down". Analyzing the other constructs, it can be seen that this approach considers the socio-technical system, the work system as a whole and the organization of work. In addition, the expected results are the design of organizations and work systems and the optimization of organizational performance.

The definition established by the authors was, finally, compared with the definition of ergonomics of the IEA and ABERGO. Thus, it was concluded that the differential of macroergonomics as a subdiscipline of ergonomics is in the design of the work system from the sociotechnical system, aiming to optimize the performance of the entire system. It is understood that macroergonomics is an approach to ergonomics that contemplates both human well-being and system performance, standing out in terms of productivity gains.

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