



ERGONOMIC ANALYSIS APPLIED IN A BAJA COMPETITION TEAM WORKSHOP

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Abstract

In the university environment, Baja SAE competition teams involve students in the development of projects, from the conception to the construction of a prototype car, simulating real work conditions. This article aimed to perform an ergonomic analysis of the work applied in the workshop of a Baja competition team. From an ergonomic mapping form, the demands related to the welding activity were obtained. Using the FMEA method, the ergonomic risk levels of the observed items were calculated, with two items standing out: inadequate postures and lack of safety. An analysis of the work postures was then carried out using the ergonomic physical assessment tools - OWAS and RULA. The results demonstrated the need for intervention and corrections, and some recommendations were proposed, among them: an adjustable welding bench design with footrest, in addition to suggestions to contribute to the establishment of a culture of PPE use. After the recommendations were made, the FMEA tool was applied again, which demonstrated a significant improvement in the levels of ergonomic risk associated with the items evaluated in this work environment.

Keywords: Ergonomic Work Analysis; RULA; OWAS; FMEA.

1. INTRODUCTION

The Industrial Revolution, which took place in the mid-eighteenth century, resulted in a change in the relationship between people and work. With technological and industrial development, there was a need to adapt the occupational conditions of factories to human needs and a growing concern with the health of the worker and its relationship with the workplace (SILVA, PASCHOARELLI, 2010). Thus, studies in the field of Ergonomics were intensified.

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In Brazil, a milestone in this area of study was the publication, in the 1990s, of the Ergonomics Regulatory Standard 17 - NR 17, which cites, among other determinations, the need to carry out the Ergonomic Analysis of Work - AET in order to evaluate the working conditions to the psychophysiological characteristics of the worker (BRASIL, 1990).

During the last few years, the transformations in the university educational system, especially in the engineering teaching environment, have brought to light several extracurricular projects, which provide students with professional experiences and make them qualified for the job market. In this context, one of the outstanding projects is Baja SAE Brasil. According to Ferreira (2011), the Baja SAE Project offers engineering students the chance to apply, in practice, the knowledge acquired in the classroom, aiming to increase their preparation for the job market. The student engages with a real case of project development, from its conception, detailed design and construction.

To this end, students are exposed to working conditions similar to those found in the real context of engineering. The construction of the prototype takes place entirely in a mechanical workshop and, thus, it is possible to analyze the ergonomic factors related to this activity. In addition, it is notorious that there are few ergonomic analyses carried out in the context of a university extension project, since they do not fit as a formal profession. Even so, they are a common activity in the daily lives of students and it is important that these types of services are analyzed.

Therefore, this article describes the performance of an Ergonomic Work Analysis (AET) applied to a Baja competition team. The next section addresses the bibliographic survey carried out, which provides a theoretical basis for the theme. Next, the methodology used to carry out the EWS is presented. Therefore, the development of the study is presented, in which the results of the analysis are demonstrated and discussed. Finally, there are the recommendations and final considerations.

2. METHODOLOGY

This work presents an exploratory approach, using as a method the case study through qualitative research, based on the Ergonomic Analysis of Work (AET), which aims to ascertain the working conditions of a given task, observing the various aspects related to it (LIMA, 2003). For Guérin (2001), the ergonomic analysis of work is an analysis of the activity that is confronted with other elements of work and, therefore, it is necessary to distinguish tasks and activities.



The study was carried out on the Baja team at a public university. As a methodological procedure, an Ergonomic Mapping Form was initially sent to one of the team members, who works in the welding sector of the workshop, whose elaboration occurred in order to meet the requirements for carrying out the AET listed in NR 17, and instructions for completion. Based on the structure of the form, an Ergonomic Risk Analysis table was elaborated, whose header contained the following information: observation variable; observed item, aspect/danger in the activity; existing administrative means of control; main consequence; root cause of the problem and the indices of the Failure Mode and Effect Analysis (FMEA) method. This tool has the following main principles: the identification of the main failures in the processes; the assessment of the risks of these failures; the prioritization of resources for the preparation of a control plan; the evaluation of the effectiveness of existing control plans and the identification of special characteristics (SANTOS, PAIXÃO, 2003).

The ratios for the FMEA form range from 1 to 3. For each item of the activity, there is a result, which is calculated by the product of the probability, severity and control indices assigned. The criteria used to determine the indices can be found in Figure 1.

Index	Probability		Severity		Control
	History	Exposure	Human	Organization	
1 - Low	No occurrences related to the agent	Short time, less than 10% of the sample time (day or cycle)	Does not generate human overload	Little or no interference in the process	There are good control plans to deal with the risk
2 - Medium	There are complaints and occurrences in terms of verbalizations	Reasonable time, from 11 to 30% of the sample time (day or cycle)	Generates situations of discomfort and fatigue	The isolated agent can interfere in momentary stops and small losses in productivity	There is a plan to deal with the risk, but there is an absence of formal procedures and there are doubts about its effectiveness
3 - High	Complaints are frequent and specific to the agent, with indicators and demonstrative records	Short time, less than 10% of the sample time (day or cycle)	Risks that can harm health, leading to injuries and absences	Involving significant production delays and reduction of planned work. Items that do not comply with current legislation	There is no plan and awareness to deal with the risk. Operational practices indicate apparent lack of control of exposure

Figure 1. Determination of FMEA indices

Finally, there is a numerical and color code that indicates the level of ergonomic risk, which ranges from 1 (trivial) to 27 (intolerable), as shown in Figure 2.



Determination of ergonomic risk levels Probability
x Gravity x Control = Ergonomic Risk Level

NRE	Risk Level	Feature	Condition	Administrative Conduct
1	Trivial	Normal Technical Action or Without Ergonomic Risk	It is a natural condition, with no significant risk.	No action is required and no documentary records need to be kept.
2 a 6	Tolerable	Unlikely, but there is a small chance of it happening.	It is considered a technical action within normality, however, due to the variability of individuals and processes, there is a low probability of a risky action occurring.	The implementation of preventive actions and risk monitoring can be studied to ensure that controls are maintained.
8 a 12	Moderate	They generate discomfort, difficulty or fatigue	Situations considered to cause discomfort, difficulty, moderate risk fatigue	Studies can be carried out to reduce the risk and the actions must be implemented within a defined period (medium term) established by the company. If complaints or occurrences of this risk appear, the period must be reduced.
18	Substantial	Significant Ergonomic Risk	Situations considered to be potentially causing injuries and accidents that generate temporary absences and significant process losses	Systematic studies of the activity must be carried out, where a short-term improvement plan approved by senior management is designed to eliminate or minimize the risk.
27	Intolerable	High Ergonomic Risk	Situations considered to be potentially capable of causing serious injuries and accidents that may result in long-term absences or functional disabilities	In addition to the systematic study of the activity, it must have an immediate term improvement plan approved by senior management to eliminate the risk. The execution of the plan must be monitored and evaluated until the elimination or minimization of risk.

Figure 2. Determination of ergonomic risk levels

From the ergonomic mapping form, the demands related to the welding activity in the Baja workshop were obtained. The answers obtained were placed in the table, in which indices were applied to determine the ergonomic risk of each aspect of the activity. Once the risks were determined, the tasks related to aspects with critical ergonomic risk (18 or more) were analyzed. The fact that the analyzed student is an undergraduate student and does not work full-time was taken into account.

For the analysis of the activities, photos, questionnaires and the application of ergonomic tools were used to confront the information obtained. With the materials and data collected in the workshop, the postural analysis tools OWAS, using the Ergolândia software, and RULA, executed through the Ergonautas web portal, were applied.

The RULA Method (Rapid Upper Limb Assessment) was developed by Dr. Lynn McAtamney and Professor E. Nigel Corlett, both ergonomists at the University of Nottingham in England. The method allows an evaluation of the biomechanical overload of the upper limbs, neck, trunk and lower limbs. The determinant of ergonomic risk in this method is represented by the postures assumed by the workers during the workday (SIQUEIRA, 2014). The OWAS Method, developed in Finland to analyze working postures in the steel industry, was proposed by three Finnish researchers; Karhu, Kansi and Kourinka in the 1970s. (PAIN et al., 2017). The name OWAS derives from Ovako Working Posture Analysing System. To test this practical tool, researchers defined 72 typical postures, resulting from various combinations. Its operation



begins with analyzes carried out on tasks performed by the student, observing the frequency and time spent in each position (WESTPHAL, 2018).

Finally, some recommendations were made based on the results obtained during the ergonomic analysis of this study. After the recommendations, the FMEA was applied again, which made it possible to verify whether the improvements would really be effective.

3. DEVELOPMENT AND RESULTS

3.1. Demand Analysis

For the development of the Demand Analysis, the Ergonomic Mapping Form was sent to the interviewee and visits were made to the headquarters of the Baja team. Through the answers obtained with the form, it was observed that the main complaints raised were related to the issue of work at the welding station and the low quality of the tools used to develop the welding activity.

The answers were placed in the Ergonomic Risk Analysis table, in each aspect/hazard item, values were assigned to the three indices necessary to determine the level of risk in the observed items.

After applying the FMEA indices to each of the items listed in the Ergonomic Analysis table, it was possible to obtain the graph shown in Figure 3, which demonstrates the levels of ergonomic risk associated with the observed items.

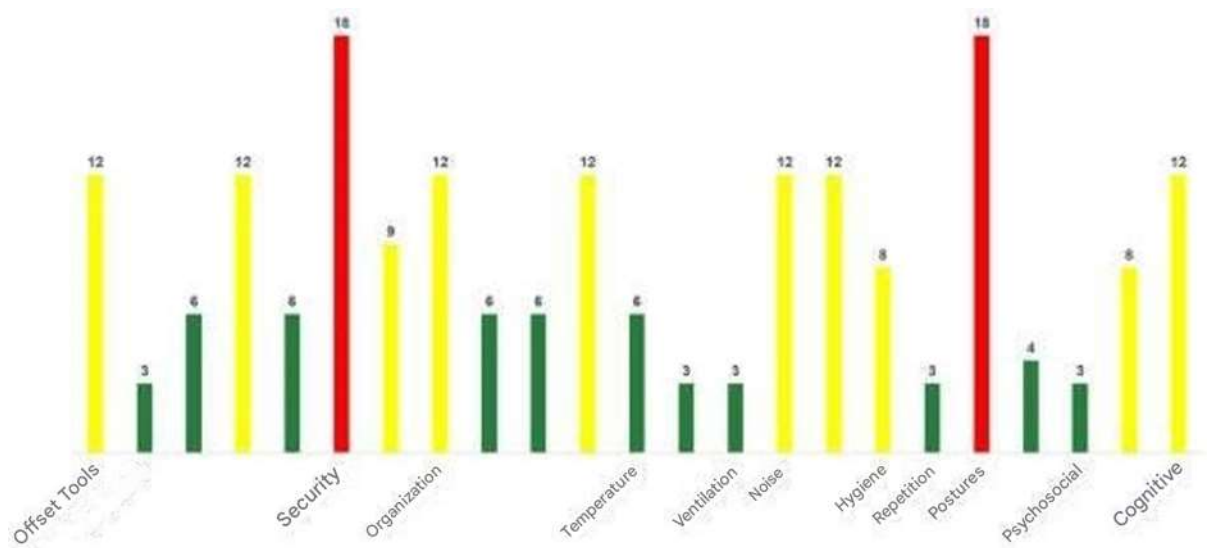


Figure 3. FMEA Chart



In view of the academic and social context in which the student is inserted, it is observed that he does not present an intolerable demand for ergonomic level. In this case, the main demands pointed out were safety and postures, which were the items with the highest level of ergonomic risk to be analyzed in this study.

3.2. Task Analysis

The interviewed student studies Electronic Engineering at a public university and found in Baja the possibility of complementing his degree, and with the experience in the team he has the opportunity to obtain knowledge that goes beyond learning in the classroom. At the age of 21, he has been on the team for 3 years and holds the position of member of the Electronics Subsystem. The team's headquarters, located on the university campus, consists of two rooms, the office and the workshop. The office is where meetings take place and programming, administrative and related functions are developed. Most of the practical development of the car prototype is developed in the workshop. In the office, shown in Figure 4, the stages of construction, assembly and maintenance of the prototype take place, where the interviewee spends 70% of his shift in the team, which corresponds to 5 hours of work, which is the part where the task of welding the components is carried out.



Figure 4. Workstation in the Baja workshop

The prescribed tasks are divided into two shifts. The student arrives at the team's headquarters and performs the following activities, as shown in Figure 5.

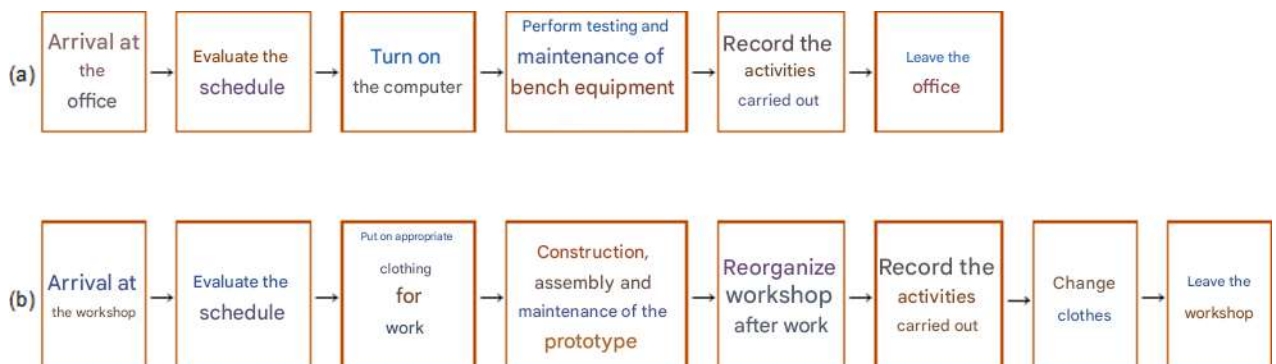




Figure 5. Prescribed tasks - (a) in the office; (b) in the Baja workshop

3.3. Activity Analysis

In the analysis of the activities, it was found that the student presents postures with indications of being the cause of the ergonomic demand presented, as they are postures maintained for long periods of time and that require effort involving the upper limbs. Figure 6 shows the postures assumed by the interviewee during working hours, in (a) there is a standing posture. In (b) the sitting posture is presented, in which it is possible to perceive that, due to the structure of the bench, there is a lack of space for the legs. In addition, the chair used does not have an adequate backrest to accommodate the interviewee's spine correctly. In both postural configurations, there is a tilt of the spine and the head in a downward position.



Figure 6. Assumed postures - (a) Standing posture; (b) Seated posture

Applying the OWAS and RULA tools to postures (a) and (b), the results presented in Table 1 were obtained.

Table 1. Results of the OWAS and RULA tools

	OWAS	RULA
Posture (a)	Action category: 2 - Corrections are needed in the near future	Score 5 or 6, action level 3: An investigation must be conducted. Changes must be made.
Posture (b)	Action category: 2 - Corrections are needed in the near future	Score 5 or 6, action level 3: An investigation must be conducted. Changes must be made.

Both the OWAS and RULA methods reached the same result, indicating that both postures can cause future problems and, therefore, deserve investigation.

4. DIAGNOSIS AND RECOMMENDATIONS



After applying the tools to the case study, it is evidenced that the analyzed activity offers some physical ergonomic risks related mainly to the postures assumed by the student. In addition, during the analyses, the relevance of the budget issue as a limiting factor for the team was perceived, causing its members to use very worn equipment and to provide all the appropriate PPE to carry out the activity. However, it was also observed that the use of PPE is not something intrinsic to the group, which does not use existing PPE.

In this context, in order for the welding activity to present less ergonomic risk and to be performed more satisfactorily by the student, some recommendations were proposed.

4.1. Organizational recommendations:

- Use of PPE already available;
- Warnings by the workshop and office about the importance of using PPE;
- Specialized training for handling the tools;
- Encouragement of breaks during the workday;
- Better planning on the eve of the Competition.

4.2. Recommendations related to the Environment:

- New Bench for the Soldering Station, whose proposal is presented below.

4.3. Bench design

For the design of a new bench, some anthropometric recommendations were respected, such as: minimum height for foot support (15 cm), leg spacing at knee (45 cm) and foot height (65 cm) and height for precision work (10-20 cm above the elbow line). In addition, it was decided to carry out an adjustable bench project, considering that the team has a high turnover of members, with different heights.

The group's budget limitation was also considered, which led to a project that could be executed with materials already available in the workshop, such as wood, SAE 1020 steel pipes and M8 screws. In addition, the manufacturing process can be entirely carried out by the team itself, since it only requires cutting, bench drilling and welding of the tubes. Figure 7 shows the projected bench.

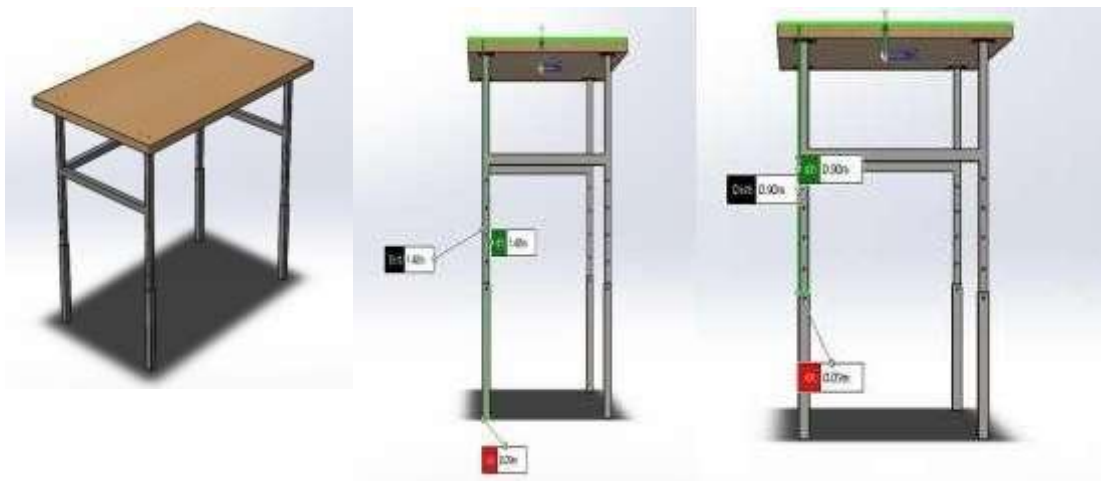


Figure 7. Adjustable Weld Bench Design

It was also decided to include a footrest, which followed the same guidelines and materials used for the proposal of the bench project, as shown in Figure 8.

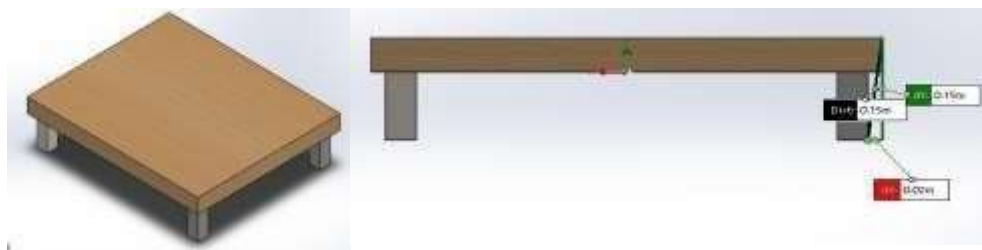


Figure 8. Footrest design

After the proposed ergonomic recommendations, a new analysis of the working conditions was performed, following the same procedures used at the beginning of the study. The result of the reapplication of the FMEA with the levels of ergonomic risk can be seen in Figure 9.

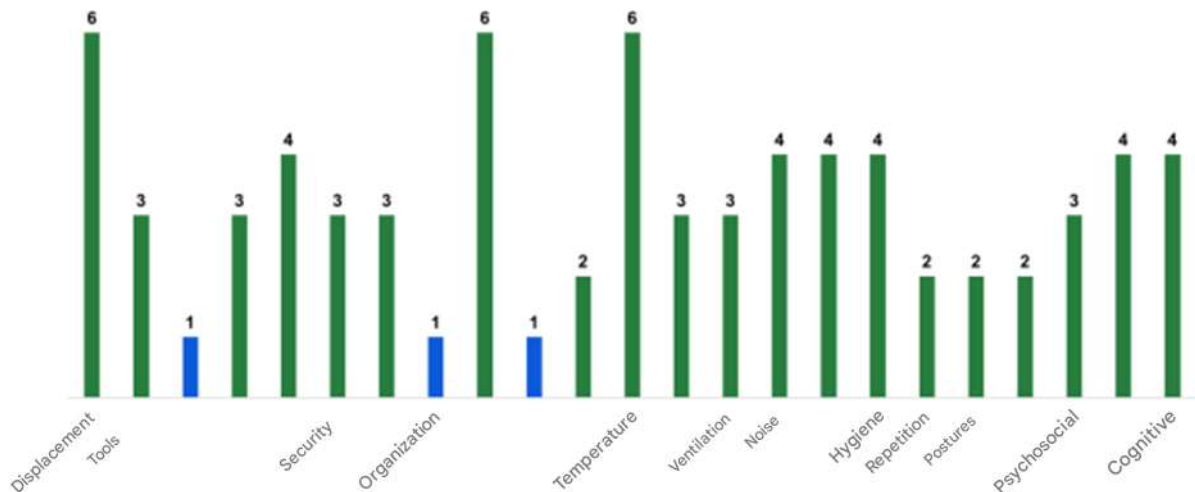


Figure 9. FMEA chart after recommendations

In Figure 9, it is possible to see a considerable decrease in ergonomic risks associated with posture and safety – with the risk level of the posture item reduced from 18 to 2 and the safety level from 18 to 3, as a result of the intervention made in the activity following the proposed recommendations.

5. FINAL CONSIDERATIONS

With technological and industrial development, studies in the field of Ergonomics have intensified considerably. In the context of this study, the main objective was to describe the performance of an AET applied in a workshop of a baja competition team.

For the development of the study, the main factors that could pose some ergonomic risk to the team members were listed through the completion of the Ergonomic Mapping Form, as well as the calculation of the critical factors of these activities. It was noted that the main demands pointed out were safety and postures, and there were none of an intolerable ergonomic level, which is due to the academic and social context in which the student is inserted.

Then, for the analysis of the tasks, the RULA and OWAS tools were applied, in order to survey the ergonomic conditions and evaluate the need for interference in the welding activity. The results indicated that both postures used for the action can cause future problems. Finally, the diagnoses and recommendations to solve the factors pointed out by the tools were presented, such as guidance on the use of PPE and the proposed bench project.



After the application of the recommendations presented, a new FMEA graph was generated and the results were satisfactory, since all risks are in acceptable ranges.

For future works, it is suggested that the application of the AET be done with other university extension projects, so that it is possible to observe if the solutions presented by the present work apply in a more generic way in other organizations.

REFERENCES

- ARAÚJO, Bianca Maros de et al. Aplicação de Análise Ergonômica de Trabalho em Empresa Metalúrgica. X Congresso Brasileiro de Engenharia de Produção. 2020. Disponível em: <https://aprepro.org.br/conbrepro/2020/anais/arquivos/09272020_160935_5f70ed8376cc5.pdf>. Acesso em: 16 de maio de 2021.
- BRASIL. NR 17-Ergonomia. Portaria MTPS n.º 3.751, de 23 de novembro de 1990. Disponível em: <<https://www.gov.br/trabalho/pt-br/inspecao/seguranca-e-saude-no-trabalho/normas-regulamentadoras/nr-17.pdf/view>>. Acesso em: 15 de maio de 2021.
- FERREIRA, Elkis Gomes. Influências do Projeto Baja SAE no ensino da engenharia e no desenvolvimento do aluno. 2011. 1 CD-ROM. Trabalho de conclusão de curso (bacharelado - Engenharia Mecânica) – Universidade Estadual Paulista, Faculdade de Engenharia de Guaratinguetá, 2011. Disponível em: <<http://hdl.handle.net/11449/119038>>.
- GUÉRIN, F. Compreender o trabalho para transformá-lo: a prática da ergonomia. São Paulo: Blücher: Fundação Vanzolini, 2001. Disponível em: <https://books.google.com.br/books?id=qkniDwAAQBAJ&printsec=frontcover&hl=pt-BR&source=gbs_atb#v=onepage&q&f=false>. Acesso em: 16 de maio de 2021.
- LIMA, João Ademar de Andrade. Metodologia de Análise Ergonômica. Monografia (Especialização em Engenharia de Produção) Departamento de Engenharia de Produção UFPB. João Pessoa. 2003.
- MOSER, A. D. et al. Método de Análise Postural e Contribuição do Sistema OWAS. Congresso Brasileiro de Ergonomia, X, e Encontro Pan-Americano de Ergonomia, I. Anais eletrônico, 2000, Rio de Janeiro-RJ, p. 33/51.
- PAIN, Cléverson et al. Análise Ergonômica: Métodos Rula e Owas aplicados em uma Instituição de ensino superior. Revista Espacios. v. 38. n. 11. p. 22. 2017. Disponível em: <<https://www.revistaespacios.com/a17v38n11/a17v38n11p22.pdf>>. Acesso em: 15 de maio de 2021.
- SANTOS, Eduardo Ferro dos., PAIXÃO, Antônio. Análise de riscos ergonômicos através da adaptação do FMEA como ferramenta de avaliação e gerenciamento. XXIII ENEGEP. Ouro



Preto. 2003. Disponível em:<<https://xdocs.com.br/doc/analise-de-riscos-ergonomicos-atraves-da-adaptaao-do-fmea-4loy69dw3ln3>>. Acesso em: 16 de maio de 2021.

SILVA, José Carlos Plácido da., PASCHOARELLI, Luís Carlos (orgs). A evolução histórica da ergonomia no mundo e seus pioneiros. Cultura Acadêmica. Editora UNESP. São Paulo. 2010. Disponível em:
<<https://repositorio.unesp.br/bitstream/handle/11449/110770/ISBN9788579831201.pdf?sequence=1&isAllowed=y>>. Acesso em: 15 de maio de 2021.

WESTPHAL, Boris Hugo. Utilização do método OWAS para avaliação da postura dos trabalhadores: estudo de campo em uma indústria de autoadesivos. Monografia para Especialização em Engenharia de Segurança do Trabalho da Universidade Tecnológica Federal do Paraná. Londrina. 2018.

SIQUEIRA, Otávio Cardoso de. Análise Ergonômica do posto de trabalho do operador de produção em uma indústria de injeção plástica utilizando o método Rula(Rapid Upper Limb Assessement). Monografia para obtenção do título de especialização no Curso de Pós Graduação em Engenharia de Segurança do Trabalho da Universidade Tecnológica Federal do Paraná, UTFPR. Curitiba. 2014.