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ERGONOMIC ANALYSIS APPLIED IN A BAJA COMPETITION TEAM WORKSHOP

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SUMMARY: In the university environment, Baja SAE competition teams involve students in the development of projects, from conception to the construction of a car prototype, simulating real working conditions. This article aimed to carry out an ergonomic analysis of 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 working postures was then carried out using ergonomic physical assessment tools - OWAS and RULA. The results demonstrated the need for intervention and corrections, with some recommendations being proposed, including: an adjustable welding bench project with foot support, as well as suggestions to contribute to the establishment of a culture of PPE use. After making the recommendations, 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

INTRODUCTION

The Industrial Revolution, which occurred in the mid-18th 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 worker health and its relationship with the job work (SILVA, PASCHOARELLI,

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2010). Thus, studies in the field of Ergonomics intensified. 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 Work Analysis - AET in order to of evaluating working conditions to the psychophysiological characteristics of the worker (BRASIL, 1990).

During recent years, 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 highlighted 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 gets involved 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 engineering context. The construction of the prototype takes place entirely in a mechanical workshop and, therefore, it is possible to analyze the ergonomic factors related to this activity. Furthermore, it is clear that there are few ergonomic analyzes carried out in the context of university extension projects, as they do not qualify as a formal profession. Still, they are a common activity in students' daily lives 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 bibliographical survey carried out, which provides theoretical basis for the topic. Next, the methodology used to carry out the AET is presented. Subsequently, the development of the study is presented in which the results of the analysis are demonstrated and discussed. Finally, there are recommendations and final considerations.

METHODOLOGY

This work presents an exploratory approach, using case study as a method through qualitative research, based on Ergonomic Work Analysis (AET), which aims to investigate the working conditions of a given task, observing the various related aspects to her (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 of 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, which was prepared in order to meet the requirements for carrying out the AET listed in NR 17, and instructions filling. Based on the structure of the form, an Ergonomic Risk Analysis table was created, whose header contained the following information: observation variable; item observed, 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 method - FMEA (Failure Mode and Effect Analysis). This tool's main principles are: identification of the main flaws in processes; assessing the risks of these failures; the prioritization of resources for the preparation of a control plan; evaluating the effectiveness of existing control plans and identifying special characteristics (SANTOS, PAIXÃO, 2003).

The indices 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 assigned probability, severity and control indices. The criteria used to determine the indices can be found in Figure 1.

Index	Probability		Gravity		Control
	History	Expo sição	Human	Organization	
1 - Baixo	No occurrence related to the agent	Short time, less than 10% of sampling time (journey or cycle)	Do not generate overloads human	Little or none interference in process	There are good plans of control to deal with the risk
2 - Médio	There are complaints and occurrences in terms of verbalizations	Reasonable time, from 11 to 30% of sampling time (journey or cycle)	Generate situations discomfort and fatigue	The isolated agent can interfering with stops momentary and small losses in the productivity	There is a plan to deal as a risk, but there is absence of formal procedures and there are doubts about your effectiveness
3 - Alto	The complaints are fre hot and specific to the agent, with indicators and records demonstratives	Short time, less than 10% of sampling time (journey or cycle)	Risks that can harm to health, leading to le sions and departures	Implying delays significant of production and reduction of planned work. Items that; do not meet the current legislation	There is no plan and awareness to cope with the risk. The practices operations indicate apparent lack of control exhibition

Figure 1. Determination of FMEA indices

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

Determination of ergonomic risk levels
Probability x severity x Control = ergonomic risk level

NRE	Level of Risk	Feature	Condition	Administrative Conduct
1	Trivial	Normal Technical Action or without risk Ergonomic	And a natural condition with no risk significant	No action is required and no registration documentation needs to be maintained.
2 to 6	Tolerable	Improbable, but there are small possibilities of occur	It is considered a technical action within the normal, but due to variability of individuals and processes, there a low probability of an risky action	One can study the implementation of actions prevention and risk monitoring for ensure that controls are maintained.
8 to 12	Moderate	Generate discomfort, difficulty or fatigue	Situations considered to cause discomfort, difficulty, risk fatigue moderate	Studies can be done to reduce the risk and actions should be implemented in a period defined (medium term) established by the company. If complaints or occurrences of this risk, the term should be reduced.
18	Substantial	Ergonomic Risk Significant	Situations considered as potentially causing injury and accidents that lead to absences temporary and process losses significant	Systematic studies of the activity, where a plan for the improvement of short term approved by senior management for eliminate or minimize risk.
27	Intolerable	High Ergonomic Risk	Situations considered as potentially causing injuries and serious accidents that can lead to long-term or functional disabilities	In addition to the systematic study of activity, it should have an immediate improvement plan approved by senior management to eliminate risk. A implementation of the plan should be monitored and evaluated up to the elimination or minimization of risk.

Figure 2. Determination of ergonomic risk levels

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

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

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 for an assessment 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 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 Analyzing System. To test this practical tool, researchers defined 72 typical postures, resulting from different combinations. Its operation begins with analyzes carried out on student tasks, 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.

DEVELOPMENT AND RESULTS

Demand Analysis

To develop the Demand Analysis, the Ergonomic Mapping Form was sent to the interviewee and visits were made to the Baja team's headquarters location. Through the responses 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 carry out the welding activity.

The answers were placed in the Ergonomic Risk Analysis table, in each aspect/danger 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 presented in Figure 3, which demonstrates the levels of ergonomic risk associated with the observed items.

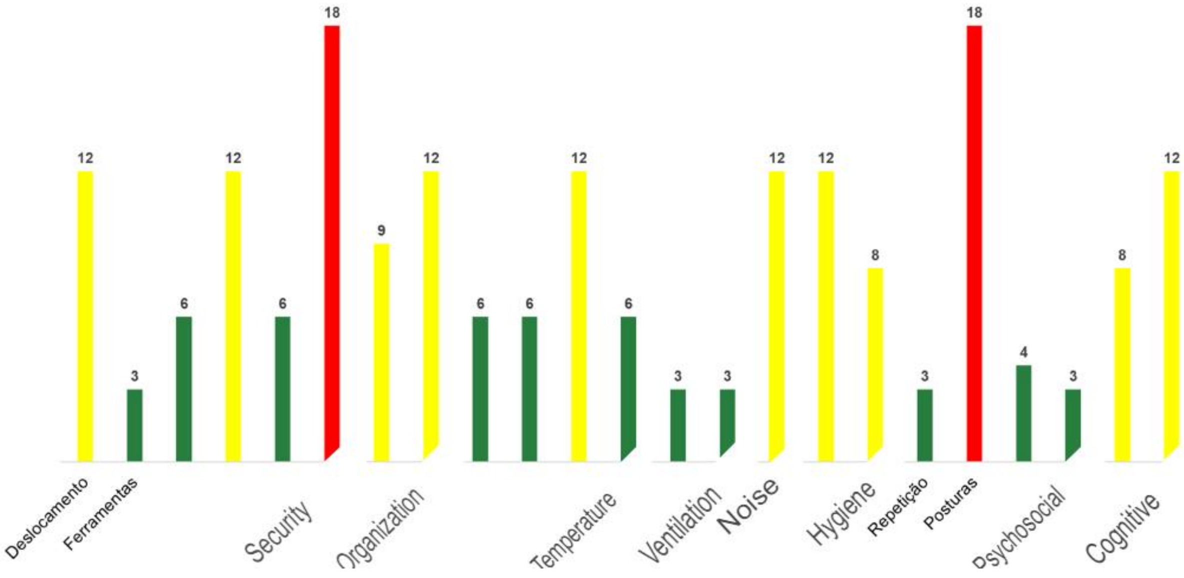

Figure 3. FMEA chart

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

Task Analysis

The student interviewed is studying Electronic Engineering at a public university and found in Baja the possibility of complementing his degree, and with his experience on the team he has the opportunity to obtain knowledge that goes beyond learning in the classroom. At 21 years old, he has already been with 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 carried out. Most of the practical development of the car prototype is carried out in the workshop. In the office, shown in Figure 4, the stages of construction, assembly and maintenance of the prototype take place, a place where the interviewee spends 70% of his shift in the team, which corresponds to 5 hours of work, this being the part

Figure 4. Workstation in the Baja workshop

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

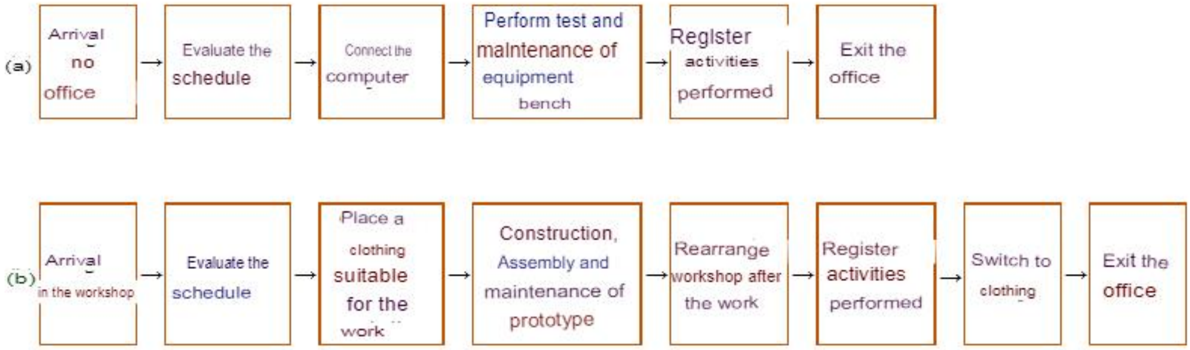

Figure 5. Prescribed tasks - (a) in the office; (b) in the Baja workshop

Activity Analysis

In the analysis of the activities, it was found that the student presents postures that indicate that they are 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 see that, due to the structure of the bench, there is a lack of space for the legs. Furthermore, the chair used does not have an adequate back to accommodate the interviewee's spine correctly. In both postural configurations, the spine is tilted and the head is in a downward position.

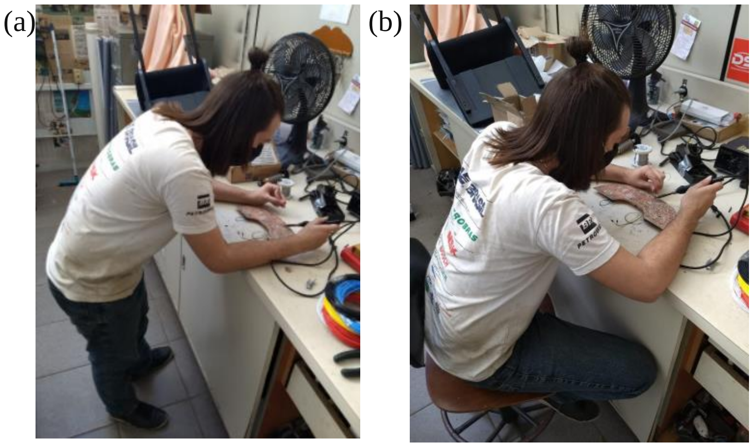

Figure 6. Postures assumed - (a) Standing posture; (b) Sitting posture

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 needed in the near future	Score 5 or 6, action level 3: An investigation should be carried out. Changes must be introduced.
Posture (b)	Action Category: 2 - Corrections needed in the near future	Score 5 or 6, action level 3: An investigation should be carried out. Changes must be introduced.

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

DIAGNOSIS AND RECOMMENDATIONS

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

In this context, so that the welding activity presents less ergonomic risk and is carried out more satisfactorily by the student, some recommendations were proposed.

Organizational Recommendations:

- Use of already available PPE;
- Notices from the workshop and office about the importance of using PPE;
- Specialized training for handling tools;
- Encouraging breaks during the workday;
- Better planning before the Competition.

Recommendations related to the Environment:

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

Bench design

For the design of a new bench, some anthropometric recommendations were respected, such as: minimum height for foot support (15 cm), spacing for legs at knee height (45 cm) and feet (65 cm) and height for precision work (10-20 cm above the elbow line). Furthermore, 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 budgetary limitations were also considered, which led to a project that can be executed with materials already available in the workshop, such as wood, SAE 1020 steel tubes and M8 screws. Furthermore, the manufacturing process can be entirely carried out by the team itself, as it only requires cutting, bench drilling and welding of the tubes. Figure 7 shows the designed bench.

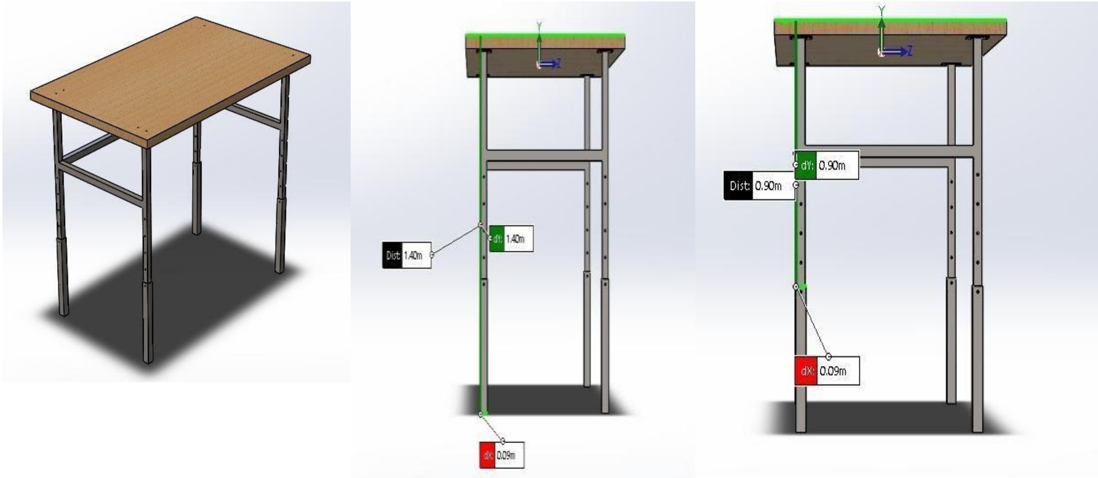

Figure 7. Adjustable welding bench design

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

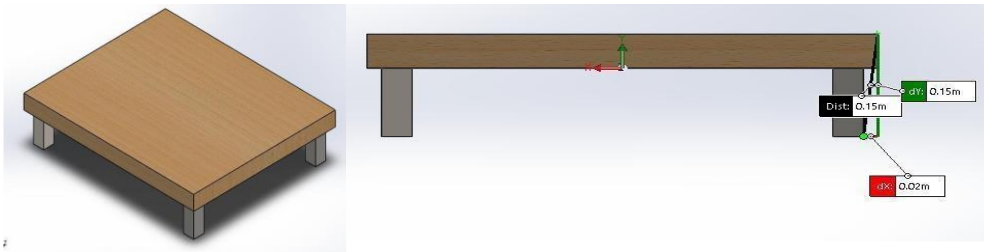

Figure 8. Footrest design

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

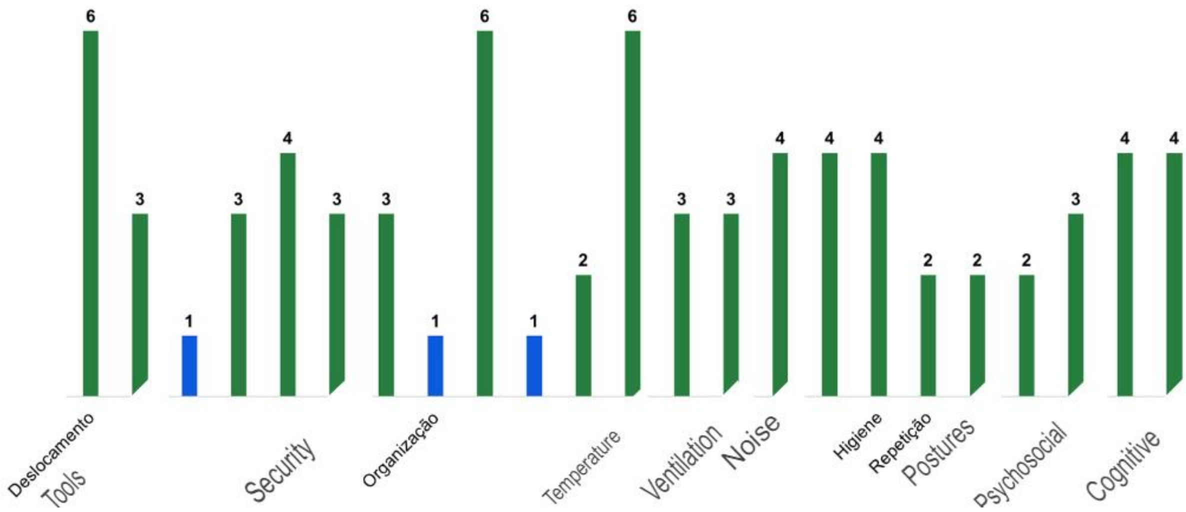

Figure 9. FMEA chart after recommendations

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

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.

To develop the study, the main factors that could pose some ergonomic risk to team members were listed by completing the Ergonomic Mapping Form, as well as calculating the critical factors of these activities. It was noted that the main demands highlighted were safety and postures, and there were none of intolerable ergonomic levels, which is due to the academic and social context in which the student is inserted.

Then, to analyze the tasks, the RULA and OWAS tools were applied in order to assess ergonomic conditions and assess the need for interference in the welding activity. The results indicated that both postures used for the action can cause future problems. Finally, diagnoses and recommendations were presented to resolve the factors highlighted by the tools, such as guidance regarding the use of PPE and the proposed bench design.

After applying the recommendations presented, a new FMEA graph was generated and the results were satisfactory, since all risks were within acceptable ranges.

For future work, it is suggested that the application of AET be carried out with other university extension projects, so that it is possible to observe whether the solutions presented in this work apply more generally in other organizations.

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