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Ergonomic Analysis Of Work In Masonry Wall Execution

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ABSTRACT

Civil construction is responsible for many occupational accidents in Brazil, due to the exposure of employees to various risk factors. The present study aims to perform an ergonomic work analysis (AET) in the execution of sealing masonry to analyze, diagnose and correct work situations that are not in accordance with NR17. The methods used for analysis were RULA and OWAS through on-site observation, it is possible to classify the postures. The results obtained showed high risk scores for certain members and acceptable for others. Through the results, it is concluded that several postures need corrections in order to ensure the health and physical integrity of the worker.

KEYWORDS: Construction. Ergonomics. Ergonomic analysis.

1. Introduction

O incidence of workplace accidents in Brazil, particularly in the construction sector, remains high compared to other countries, leading to significant economic and social problems (INSS, 2018). Brazil accounts for 8.9% of all accidents in the construction industry, with 42.8% occurring in building construction. This index reflects precarious conditions on construction sites concerning training, hygiene, safety, ergonomics, and the work environment (BRASIL, 2014).

High rates of disability, illness, and fatalities result from the poor conditions on construction sites. Additionally, workers in this sector are exposed to high workloads compared to other industries due to rework, excessive work, and piece-rate payment practices (WINTER et al., 2015).

Injuries caused by Repetitive Strain Injuries/Work-Related Musculoskeletal Disorders (RSI/WRMD) are leading to irreversible consequences for workers, potentially resulting in permanent disability. Such consequences can become chronic and hinder even the most basic daily activities (WENDERSON; VIRGÍLIO, 2013).

The Ergonomic Work Analysis (EWA) aims to apply theoretical knowledge of ergonomics to analyze, diagnose, and correct work situations to prevent more harmful consequences, focusing on the physical well-being of workers (CHO et al., 2019).

The Ergonomics Regulatory Standard (NR17) is a regulation that establishes standards to enable adaptations to working conditions, with the aim of providing greater comfort, safety, and efficiency at work (BRASIL, 2007).

The objective of this study is to conduct an ergonomic analysis of work in masonry wall execution to examine, diagnose, and correct work situations that do not comply with ergonomic principles, thus respecting the minimum conditions required by NR17 and preserving the health of workers.

2. Theoretical Framework

2.1. Accidents And Risks In The Construction Industry

Workplace accidents bring serious consequences to the health of the worker, resulting in professional incapacities. To prevent these incidents, it is essential for workers to undergo training in the area where they will be working and to be properly equipped with personal and collective protective gear, preserving against accidents that are imminent in the work area (MONTEIRO; BERTAGNI, 2000).

Problems in the construction industry arise due to the risks faced by workers, risks that are evident in the work environment. In the event of accidents, companies aim to implement training on imminent risks in each work situation, creating alternatives to minimize accidents (VALINOTE; PACHECO; FORMIGA, 2014).

Activities in the construction industry are exposed to unwanted risks that can lead to sequelae, death, or even permanent or temporary work disability. The Regulatory Standard for Specialized Services in Engineering Safety and Occupational Medicine (NR4) is fundamental for the organization of construction sites. It is extremely important for workers to be aware of the hazards during execution, aiming at the ability to deal safely with the work (BARBOSA FILHO, 2010).

2.2. Ergonomics

In the year 1940, ergonomics emerged, with its origin associated with the needs of war, linked to the construction of weaponry according to the characteristics of human beings (OAQUIM, 2004).

Ergonomics is an approach focused on a structured discipline encompassing all perspectives of human activity. To understand what happens and to be able to intervene in activities carried out during work, it is necessary for the approach to cover the entire environment, in all aspects, including physical and cognitive aspects, as well as social, organizational, environmental, among others (MASCULO; VIDAL, 2011).

The purpose of ergonomics is to improve and preserve the health and well-being of workers and also to ensure the optimal functioning of the technical system, aiming from both the production and safety perspectives (PATTERSON; ABRAHÃO, 2011).

Ergonomics is directly linked to the science of comfort, well-being, improvement in work-related activities, productivity capacity, full safety, among others. The objective, however, is to provide workers with favorable working conditions, with the intention of making the activity more productive through a healthier and safer working environment, allowing for fewer physical demands and wear and tear, resulting in a reduction of harm (BARBOSA FILHO, 2010).

Applied knowledge about humans to problems in the human-work relationship contains various methods of studying and researching human performance in the service, so it is understood that ergonomics is a technology, that is, a set of knowledge. The focus of ergonomics is to modify the work system, effectively contributing to the performance of the worker. It is an expert process in which the ergonomist, through their knowledge and participation, seeks to implement a solution to the problem, contributing with suggestions for the improvement of activities, bringing results from a study of the situation (MORAES; MONT'ALVÃO, 2000).

2.3. Ergonomics In The Construction Industry

The construction industry presents the highest rates of workplace accidents, as it involves a wide variety of risks in its stages, and ergonomic methodologies are still inadequately implemented in this sector (GUIMARÃES; MARTINS; BARKOKÉBAS JUNIOR, 2015).

This is due to the fact that activities are scattered, performing various functions simultaneously, and there is a lack of organization among workers (IIDA, 2005). According to the author, construction activities are characterized by manual labor, involving strenuous and complex tasks, often performed by workers with insufficient or no training. The lack of training in companies leads inexperienced employees to learn on the job by observing colleagues, especially in roles like a laborer, which rarely requires complete education.

Activities performed by workers are exposed to improper postures, causing discomfort and leading to changes in the functioning of the body due to increased fatigue. Excessive load brings circulatory consequences and muscular fatigue resulting from the work performed (TORRES, et al., 2006).

In the construction industry, ergonomic analysis is still underutilized, especially in building construction. The tools and manual equipment used by workers are often damaged and unsuitable for a particular job area. This is because companies prioritize productivity over safety in the workplace (RAJABALI, HOSSEIN, MORTEZA, 2018).

Ergonomics is often used as a preventive measure, aiming to eliminate problems in various work activities. Regarding lifting loads, it is sometimes necessary to use machines/equipment that facilitate their transport because excessive weight lifting can cause serious damage to the spine (IIDA, 2005).

3.1. Tools Of Ergonomic Analysis

The Ergonomic Work Analysis (EWA) is a tool used to apply ergonomic knowledge, analyze, diagnose, and correct work situations, classifying the activities performed by individuals at work and guiding necessary changes for better working conditions. The goal of EWA is to assess the actual working conditions, the functions performed by the worker, and the actual conditions carried out in the work (FERREIRA, 2015).

NR17 contributes to ergonomics with assessment tools to achieve work organization through ergonomic principles, aiming to improve comfort and safety conditions (BRASIL, 2007).

There are various tools for conducting ergonomic analysis, and the choice of which tools to use should be based on the function being analyzed and the intended objectives (SAAD; XAVIER; MICHALOSKI, 2003).

Some methods used to analyze working conditions, such as EWA, are essential for the analysis and organization of work, as well as the work environment and the activities performed, making them adaptable to the worker's needs (SHIDA; BENTO, 2012).

It is important to note that to conduct an ergonomic work analysis, it is fundamental for the proposed assessment imposed by the evaluator to seek an understanding of the workstation's reality (FERREIRA, 2015).

The challenges in ergonomic analysis lie in correcting and analyzing improper postures in the work environment (IIDA, 2005).

3.1.1. OWAS (OVAKO WORKING ANALYSIS SYSTEM)

In 1977, the OWAS method was developed by a group of ergonomists, engineers, and workers in Finland. Starting from 1991, technological versions of computers emerged, leading to the development of software to quickly understand ergonomic assessments and make them available to ergonomists (KONG et al., 2018).

OWAS is a method for evaluating the physical load resulting from postures during work. This method is defined as the ability to absolutely assess the positions used in task performance. However, it obtains less precise assessments than those mentioned earlier. The capability to consider prolonged postures makes OWAS, despite being an old method, one of the most widely used in posture load assessments (LIMA, 2019).

This method is observational, meaning it is based on observations of various types of postures adopted in task performance at work. Posture observations are classified into 252 possible combinations based on the positions of the worker's back, arms, and legs, as well as the loads to which the worker is subjected, defining the adopted posture (GÓMEZ-GALÁN et al., 2017).

3.1.2. RULA (RAPID UPPER LIMB ASSESSMENT)

The Rapid Upper Limb Assessment (RULA) method was created in the mid-1990s by McAtamney and Corlett from the University of Nottingham (Occupational Ergonomics Institute) to analyze workers' response to factors leading to high postural load and potential disorders in the upper limbs. For risk analysis, the method considers the position, duration, and frequency when maintained (HABIBI; MOHAMMADI; SARTANG, 2017).

RULA is a method that assesses individual positions based on the evaluated postures habitually performed at work. If a higher postural load is assumed, positions with the longest duration or highest frequency deviating the most from the neutral position will be selected (SOUZA; MAZINI FILHO, 2017).

The method assigns scores aiming for a certain action level established for specific positions. This action level indicates whether a particular position is acceptable, suggesting changes or redesigns necessary for the position. In summary, the method allows the evaluator to observe and identify problems arising from ergonomics due to excessive postural loads (LIMA, 2019).

4. Methodology

For the development of this work, the following methods of Ergonomic Work Analysis were used: Ovako Working Analysis System (OWAS) and Rapid Upper Limb Assessment (RULA).

The research design characterizes an exploratory study with a qualitative approach, aiding in data collection to generate accurate results. The sampling is non-probabilistic and intentional, where the evaluated individuals are those working in the sector.

The OWAS method involves evaluations of the lower and upper limbs based on the manual of postures. Each posture is assigned a postural code consisting of 4 digits. The first digit depends on the position of the worker's back in the evaluated posture, the second on the position of the arms, the third on the position of the legs, and the fourth on the moved load. These codes are assigned based on tables with specific values attributed to certain analyzed postures. Unlike other postural assessment methods, OWAS is characterized by its ability to assess all positions adopted during task performance together, according to Table 1.

Table 1 – Categories of risks for corrective actions

Category	Effect of posture	Corrective action
1	Normal and natural posture, without harmful effects on the musculoskeletal system	No corrective action needed
2	Posture with the potential to cause damage to the musculoskeletal system	Corrective actions are needed in the near future
3	Postures with harmful effects on the musculoskeletal system	Corrective actions as soon as possible
4	The load caused by this posture has extremely harmful effects on the musculoskeletal system	Corrective actions are needed immediately

Source: Guérin (2011)

The RULA method is divided into two groups, GROUP A: arms, forearms, and wrists, and GROUP B: legs, trunk, and neck. Scores are assigned to the analyzed areas based on the method, and values are represented for each group.

The scores were obtained through the angle of the posture in which the worker is positioned. For each body part, a method of measuring the angle is determined, and the evaluator, during analysis, will relate the angle that most closely resembles that of the proposed method.

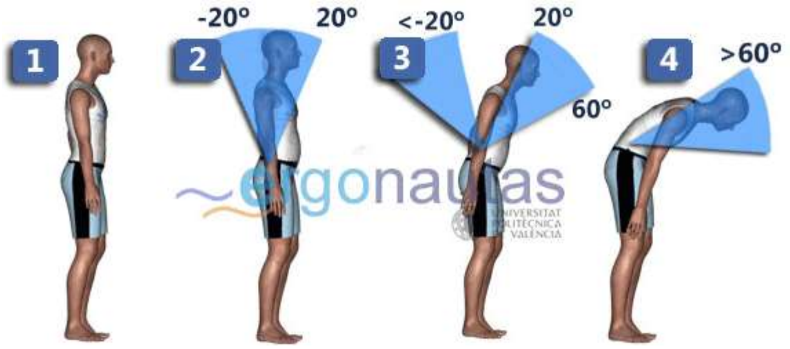
Table 2 - Analysis of Trunk Position

Classification according to the position	
Position	**Score**
Neutral Position	1
Flexion between 0° and 20°	2
Flexion > 20° and ≤60	3
Flexion > 60°	4

Source: Guérin (2011)

Subsequently, the groups present the scores in general, which consequently, depending on the analyzed posture position, the score will be increased by one point, according to each analyzed member. The final score is obtained with the corresponding modified global values.

Figure 1 – Analysis of Trunk Position



Source: Available at:<http://www.ergonautas.upv.es/metodos/rula/rula.php>

Table 3 – Modification of Trunk Position

Sum of points for each movement	
Modification	**Score**
Rotated trunk	+1
Laterally inclined trunk	+1

Source: Guérin (2011)

Figure 2 – Modification of Trunk Position

Source: Available at: http://www.ergonautas.upv.es/metodos/rula/rula.php

Firstly, two 40-minute videos were recorded, one showing the worker performing the initial rows and the other showing the worker performing the final rows. The final scores reflect proportional results to the risks involved in task execution, where scores above 4 indicate a high risk of muscular injuries. Based on the final scores, action levels ranging from level 1 to 4 are proposed for the analyzed body parts. Level 1 predicts that the assessed posture is acceptable, while level 4 indicates an urgent need for changes in the activity. Although the method takes into account other factors such as exerted forces or repetitiveness, it should be used solely to assess postural load on the upper extremities. Evaluations are individual and not based on sets or sequences of postures.

Table 4 – Risk Categories with Final Scores

Score	Level	Acting
1 or 2	1	Acceptable risk
3 or 4	2	Changes in homework may be necessary; it is advisable to further study
5 or 6	3	Task needs to be redesigned
7	4	Urgent changes in homework are required

Source: Guérin (2011)

The ergonomic work analysis was initially conducted based on the OWAS method, which is a postural assessment. Subsequently, the RULA method was employed to obtain a correct evaluation of the assessed limbs, considering the adopted posture.

1. Results And Discussion

From the results, the following worker postures during the execution of masonry were analyzed and classified. These are presented in Figures 3 and 4 for each stage (initial lower rows and final higher rows). Using the RULA and OWAS methods, classifications and scores for the limbs were obtained (tables 5 to 11).

Figure 3 – Execution of Masonry Elevation (Initial Rows)

Figure 3 is a representation of the process of raising walls, in which the evaluation is done only for the lower part, approximately 1.20m high from the masonry. In the RULA method, scores ranging from 1 to 4 are assigned, but unlike the other method, they are analyzed together with the scores. The scores are analyses based on each limb being evaluated, meaning if there is a change in any limb, a point is added to the scores. This modification follows the tables specified by RULA, where conditions for adding or even subtracting a point are assigned to each limb.

Table 5 – Classification and Score of Limbs Group A

RULA				
Group	**Limb**	**Description of the position**	**Score**	**Work stage**
A	**Arm**	Extension > 20° or Flexion > 20° and < 45°	2	**1**
A	**Forearm**	Flexion between 60° and 100°	1 +1	1
A	**Wrist**	Flexion or Extension > 0° and < 15°	2 +1	1

The scores obtained in Group A initially considered the arm score. An analysis of the position of the worker's arms was conducted, evaluating the angle formed in the arm position. A graphical representation demonstrating that the angle formed is Extension > 20° or Flexion > 20° and < 45°. The score for this evaluation is 2, according to the analysis of the table and the represented figure. No additional score was added, as the worker's shoulder is not raised.

The forearm score is obtained from the angle formed in the graphical representation of Figure 3, assessed as a score of 1, indicating Flexion between 60° and 100°. The score for the forearm is modified by a movement to one side of the body, characterized as one point added to the total limb score.

Finally, the assessment performed by Group A is the wrist score. This analysis was based on the inclination position of the wrist. The score identified that the wrist is in Flexion or

Extension > 0° and < 15°, with no modification of the wrist in the evaluation. However, there is a score for wrist rotation described as medium rotation, occurring when the worker handles materials. Therefore, one point is added to the limb score.

Table 6 – Classification and Score of Limbs Group B

RULA				
Group	**Limb**	**Description of the position**	**Score**	**Work stage**
B	Pescoço	Flexion > 20°	3 +1	1
B	Tronco	Flexion > 60°	4 +2	1
B	Perna	Weight is not distributed symmetrically	2	1

In Group B, scores are obtained from the following limbs: neck, trunk, and legs. The evaluation of the neck is conducted by analyzing the sequential figures to determine the angle formed by the worker while performing the task. According to the method's specification, the worker's neck is in Flexion > 20°, classified as a score of 3. An additional point is added in the neck modification because the worker's neck is inclined, resulting from the task's demand for movement.

For the trunk score, it is crucial to analyze the position of the worker while performing the task. In Figure 3, it is evident that the posture is with the trunk elevated, depending on the angle of trunk flexion measured between the trunk axis and the vertical. In the evaluation, this is scored as 4, describing that the worker is in Flexion > 60°. In Figure 3, the worker modifies their posture during the task, making a movement with the trunk to pick up materials behind their body and place them in the rows being executed. In this case, two points are added, one related to trunk rotation and the other to lateral trunk inclination.

Leg scores are directly related to the worker consistently performing activities in a vertical position. Therefore, the applicable score for the position in Figure 3 is assigned as 2, describing that the worker's feet are not supported or the weight is not distributed symmetrically.

Table 7 – Classification and Score

Codes (OWAS)				
Back	**Arm**	**Legs**	**Force**	**Work stage**
2	1	3	1	1

For the analysis, the limbs were separately classified according to the OWAS evaluation method. Scores ranging from 1 to 4 were assigned, with assessments based on limbs such as back, arms, and legs, in addition to analyzing the load the worker handles during the task.

The sequence of evaluations and the limbs to be analyzed are determined by the evaluator. The first analysis focused on the back position, with scores assigned based on the OWAS method. The evaluation targeted the most critical position of the worker to obtain the limb score. The worker was found in a highly curved position in the lumbar region. According to Table 7, the worker's position involves inclinations greater than 20°, considered inappropriate in the analysis, requiring postural correction due to the risk of muscular discomfort or even compromising the musculoskeletal system.

To assess the arm position, an analysis was conducted from the base tying of the masonry up to the waist region. The obtained score was 1, indicating that the worker's arms are located below shoulder level. The leg position was analyzed from picking up the brick, applying mortar to block fitting, resulting in a score of 3. A score of 3 suggests that the worker is standing with one leg extended and the other flexed, with an unbalanced weight between the two legs. These score choices are associated with the most critical positions determined by the evaluator.

Finally, the assessment focused on the load the worker is handling. According to the method, the results of the materials used in the construction site determined a load of 4.1 kg, as indicated in Table 8.

Table 8 – Weight of Materials Used on the Construction Site

Materials	Weight (kg)
Mason's trowel with mortar 4.1 kg	1,6
Ceramic Block 14x19x29	2,5
Ceramic Block 14x19x19	1
Plumb bob	0,63

With the weights of the respective materials, the score for the postural load evaluation was 1, indicating that the manipulated weight is less than 10 kg. With this information, it is possible to identify corrective measures that can be applied based on the collected data and the obtained results.

In Figure 4, the worker is in a more upright position during masonry work because the walls are above 1.50m in height. To obtain scores for lifting the upper part of the masonry, it is necessary to analyze the positions in which the worker is engaged while performing the task..

Table 9 – Classification and Score of Limbs Group

RULA				
Group	**Limb**	**Description of the position**	**Score**	**Work stage**
A	Arm	Flexion >90°	4	2
A	Forearm	Flexion between 60° and 100°	1 +2	2
A	Wrist	Flexion or Extension >0° and <15°	2 +2	2

Group A had the following evaluations: arm, forearm, and wrist. For the arm evaluation, the critical position in which the worker is located was prioritized. When analyzing Figure 4, the determinant position for the analysis was when the worker is laying the blocks. The assigned score is 4, indicating that the worker's arms are in flexion > 90°. There are no score modifications, as the worker is in a position where the shoulders and arms are not elevated; the limbs are at rest during task execution.
The score for the forearm was determined by the position of the arms, measured by the angles formed from the elbows to the hands. The evaluation was done collectively, as the positions used by the worker during execution change frequently throughout the task. The score for this evaluation was 2, indicating that the arms are in flexion < 60° or > 100°. In this position, there are modifications in the scores. According to Figure 4, the worker makes two rotations, both to one side of the body and crossing the midline. The final score will be the sum of two points, as each rotation occurring in the execution adds one point. As there are two movements happening simultaneously, according to the method's specifications, the two evaluated scores are added together.
The score for the wrist is obtained from the angle formed in flexion or extension in the neutral position. In the analysis, the worker has the wrists in flexion or extension > 0° and < 15°, classified as score 2. This occurs because when placing the block with mortar on the upper row being executed, the wrist is inclined. The modification scores for this limb are classified as score 2, indicating extreme pronation or supination, i.e., the wrists make rotational movements mainly during the placement of the rows. The score for this modification will be two points, as the wrist, in addition to rotating upwards, also rotates downwards, representing two rotations in the limb, with each rotation counted as one point.

Tabela 10 – Classificação e Pontuação dos membros Grupo B

RULA				
Group	**Limb**	**Description of the position**	**Score**	**Work stage**
B	Neck	Extension in any series	4 +1	2
B	Trunk	Flexion > 60°	4 +1	2
B	Leg	Weight is not distributed symmetrically	2	2

For the evaluation of Group B (neck, trunk, legs), analyses were based on the positions adopted in Figure 4. To obtain the score for the neck, it was necessary to assess not only the inclined position of the limb to which the worker is subjected in performing the task but also when he picks up materials for placement in the row. According to the classification, the score for this limb is 4, indicating that the neck is in extension in any series, i.e., at an angle > 0°. The modification score assessed for the neck is the sum of one point, as the worker is constantly turning his head due to the task requiring attention to all details.

The score for the trunk is assessed as 4, indicating that the worker is subjected to flexion > 60°. This is because, when handling materials, the worker is inclined. For the modification score of the trunk, the analysis was conducted based on the materials being picked up; the worker is subjected to lateral bending in the evaluated limb, adding one point.

Regarding the legs of the worker, they were classified with a score of 2. This score is directly related to the influence of the worker always being standing, describing that the worker's feet are not supported or the weight is not distributed symmetrically.

Table 11 – Classification and Score

Codes (OWAS)				
Back	**Arms**	**Legs**	**Force**	**Work Stage**
4	2	3	1	2

Firstly, an analysis of the back was conducted, assigning a score to the assessed limb based on the critical position assumed by the worker. According to the table, the worker's position involves both flexion and rotation of the trunk (or inclination) simultaneously. This is due to the height of the wall located in the shoulder region. This relationship is associated not only with the straight position when performing the service in the upper part but also when picking up the ceramic block along with the mortar. To obtain the score, it is relevant to analyze the position in which the worker has to handle the materials along with the position of the arms.

The arm position for assessment is analyzed based on the position in which the worker picks up the ceramic block and extends the arms to place the block in the row where the service is being carried out. The score assigned from the postural code was 2, describing that one of the worker's arms is located below shoulder level, and the other, or part of the other, is located above shoulder level. In other words, when handling materials used in the execution, which are below the waist, the worker lowers one arm to pick up the ceramic block and mortar. On the other hand, when lifting the masonry from the upper part, the worker extends the arms to place the block. In this case, the most critical position of the worker was evaluated, which is the arm extension during block placement.

Regarding the leg position, the analysis was based on the weight manipulated by the worker when picking up the brick, applying mortar until fitting, with an exposed load defined by the method as score 3. This describes that the worker is standing with one leg extended and the other flexed with unbalanced weight between the two.

Finally, the assessment is the load that the worker is manipulating. According to Table 8, the result of the materials used in the work was less than 4.1 kg.

2. Conclusion

Through the systematic application of the RULA and OWAS methods in the execution of masonry construction, it was possible to assess the postures to which the worker is exposed during this activity. Postures were analyzed and classified individually, considering combinations of body parts such as arm, forearm, wrist, neck, trunk, back, and legs. The OWAS and RULA methods allowed for the evaluation of whether the worker performed the task in ergonomically suitable postures or not.

The results demonstrate that the limbs to which the worker is exposed to excessive efforts during execution are considered critical. This is due to the certain wear and tear experienced by the limb and is classified as inadequate postures, considering the repetitiveness of the evaluated posture. Therefore, legs, arms, forearm, back, wrist, neck, and the force manipulated by the worker are assessed, and scores are assigned for corrective measures.

In conclusion, according to the RULA method, for limbs such as arms, forearm, and wrist, changes in task execution may be necessary, and further study is advisable. However, urgent corrections are required for the trunk and neck.

Regarding the OWAS method, corrections are needed for the legs and especially the back, which is classified as high risk. Arms and the force exerted by the worker are considered acceptable risks, and no changes are currently necessary.

It is suggested that the worker use a lumbar belt during the execution of the initial rows to reduce the risk of muscular injuries. For the final rows, it is recommended that the materials used in the task be at the worker's waist height to avoid movements with high curvature.

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