

ERGONOMIC AND BIOMECHANICAL ANALYSIS FOCUSED ON THE MANAGEMENT OF MAINTENANCE AND PUBLIC CLEANING SERVICES

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ABSTRACT

This article presents the results related to an Ergonomic Work Analysis carried out with street sweepers in the city of Florianópolis/SC, Brazil. The RULA Protocol, by McAtamney & Corlett (1993), as well as the study of Inertial Properties of the Body, by Riehle (1979), were used as tools of ergonomic and biomechanical analysis, in order to subsidize proposals to improve the management of the working environment analyzed.

KEY WORDS

Ergonomic work analysis, Biomechanical, Maintenance and public cleaning services.

1. INTRODUCTION

This article describes part of the procedures adopted during the phases of Ergonomic Work Analysis (AET, abbreviation in Portuguese) applied to the working environment of street sweepers, responsible for the maintenance and urban public cleaning services in the city of Florianópolis, Santa Catarina, Brazil. For such, two young female professionals were chosen for the analysis in a busy street in the city. In general, “the results of an AET should direct and guide modifications to improve the working conditions concerning the critical aspects evidenced” (MERINO, 2008, p. 58). Thus, the objective of the AET presented in this article is to improve the productivity and quality of the service provided by the professionals analyzed.

The main phases addressed in this research, to conduct the AET, are the phases of analysis of Demand, Analysis of the Task and Analysis of Activities. Consecrated analysis tools were used to support the systematics of the study. In this article the presentation of use of these two tools were limited to the RULA Protocol (McATAMNEY & CORLETT, 1993) and the study of Inertial Properties of the Body (RIEHLE, 1979). At the end of the analysis, recommendations are presented to improve the working environment. As highlighted by Merino (2008), this phase of elaboration of recommendations is the reason for the existence of the AET.

2. THE METHOD

2.3 Analysis of the Demand

In an AET, the phase of Analysis of Demand is the definition of the “object of ergonomic action, reformulating the problems established based on the concrete work activity” and “should contribute towards the implantation of the conditions to confront the perspectives”. (GUÉRIN *et.*

al., 2001, p. 40-42). Thus, it explains that the problem to be analyzed involves the working environment of street sweepers, or 'garis', as they are registered in their employment record.

Vasconcelos (2008) highlights that the profession of *garis* in the contemporary urban scenario does not always correspond to the work or study analysis related to the health of the workers, and their work load increases with the growth of the population in the cities. This way, these professionals need to respond to the different interests involved, like the hiring companies of the communities benefitted by their work and the workers themselves. "To achieve these objectives, the workers need to deal with different requirements of time, quality and safety, developing strategies and regulations in order to maintain an acceptable workload" (VASCONCELOS, 2008, p. 51).

Therefore, this article also strengthens the perception of relevance of the working environments related to public cleaning, so that the work is registered through kinometry, in the streets of the city of Florianópolis, Santa Catarina, Brazil, with the participation of professionals from the company responsible for the maintenance and public cleaning of the city. All of the people approached agreed to cooperate with this study. It was verified, firstly, that the professionals observed during the analysis complained about pains in their arms, forearms and hands.

2.2 Analysis of the Task

The phase of "Analysis of the Task" corresponds, firstly, to a set of objectives given to the operators, and to a set of prescriptions defined externally to achieve these particular objectives". (GUÉRIN *et. al.*, 2001, p. 25). In this phase of the analysis, the tools and conceptions originating from the areas of Ergonomics and Occupational Biomechanics were applied.

As explained previously, the professionals chosen for this analysis were young females, and were working in a busy avenue in the city of Florianópolis. As a result of performing their duties in pairs, aspects related to both the professionals are explored in this article, also by the fact of performing different procedures, or actions. The main reason for choosing female workers for the analysis is that the high number of job vacancies for this position refers to the recruitment and selection of women. In terms of clothing, the company offers a uniform, a cap and gloves to the employees. Regarding the work equipment, the material supplied is a large solid wooden broom, a metal shovel and a cart to put the waste in, approximately a meter high, with a trash can and wheels made of polymer.

Based on the actions made by the workers in their working environment, it is possible to obtain data related to the physical requirements of the task analyzed. As the actions performed differ among themselves, a decision was made to use the different tools in different postural situations, which could generate relevant information to understand the work performed and, also, that were appropriate for the analysis of each of the images captured. Therefore, the RULA Protocol, by McAtamney and Corlett (1993), was applied to worker 1 while sweeping, per se, and the study of Inertial Properties of the Body, by Riehle (1979), was applied to worker 2, during the collection of waste. For the first application, the images captured presented in Figure 1 served as parameter for the identification of physical requirements on segments of the body while sweeping.



Figure 1 - Images captured of worker 1 for the ergonomic analysis

Based on the images, therefore, applied to the RULA method, abbreviation that means 'Rapid Upper Limb Assessment'. According to the authors of RULA, it is a method of ergonomic study developed for use in investigating workplaces where disorders related to the work of upper limbs are reported. It is important to note that the work analyzed in this article fits this definition, especially the action of sweeping. The tool enables a quick evaluation of the neck, torso and upper limbs, together with the muscular function and the external loads experienced by the body (McATAMNEY and CORLETT, 1993).

The coding system of the RULA was used to generate an action list that indicates the level of intervention necessary to reduce the risks of injury due to the physical load on the worker analyzed. The system generated a final score equal to 6 (six) for the work analyzed, determining a level of action 3 (of 4 levels), because a score of 5 or 6 indicates that an investigation should be made and soon changes will be necessary in this working environment (McATAMNEY and CORLETT, 1993, p. 96). It is important to note that Signori, Guimarães and Sampedro (2004), on analyzing the applicability and reliability of nine instruments used by ergonomists in the evaluation and classification of the risks of occurrence of D.O.R.T./L.E.R., the instrument that presented the smallest variation of results in the general analysis of the environment was the Rula Protocol. Evidently, the tool per se is not sufficient for a complete ergonomic analysis. Before, its objective was an initial investigation.

Before presenting the complementary details related to the task of analysis by worker 2, it is necessary to establish the axis of rotation related to the body segments analyzed in this case, as presented by Riehle (1979). The information contained in the work of Riehle (1979) is important to locate the aspects in the image captured related to work carried out by the second worker. However, besides the location of the axis of rotation, it is necessary to determine the center of mass of each body segment, in order to obtain the center of gravity of the worker in specific situations. In order to do this, the data related to inertial properties was analyzed, including each sector, its center of mass as per the proximal radius, its weight percentage in relation to the organism and its respective ratio. The data is shown in Table 1.

Sector	CM – proximal radius	Weight (%)	Ratio
Head	-	7.8	-
Torso	44%	51	0.786
Arm	43%	2.7 (x2)	0.754
Forearm + hand	64%	2.2 (x2)	1.778
Thigh	43,3%	9.7 (x2)	0.764
Leg + foot	61%	6 (x2)	1.564

Table 1 – Inertial Properties of the human body (RIEHLE, 1979)

With this data, as per the location of each set of spatial coordinates X and Y, related to a specific posture of the worker analyzed, therefore, the centers of mass of each body segment can be located. Finally, the center of gravity of the subject analyzed was obtained by applying the following equation:

$$CG = \frac{\sum_{i=1}^n \text{Torques}}{\text{weight}}$$

For this study, the data was calculated with the assistance of a spreadsheet, where the data related to the spatial location of the axis of rotation was filled in, generating the centers of mass of each segment and, consequently, the center of gravity of the worker in the posture analyzed. The Spreadsheet constructed its data and one of the postures analyzed in the image captured can be seen in Figure 2. In the image, the yellow dots refer to the axis of rotation, the orange dots refer to the centers of mass of each body segment and the red dot to the center of gravity of the limbs on the left side of the body.

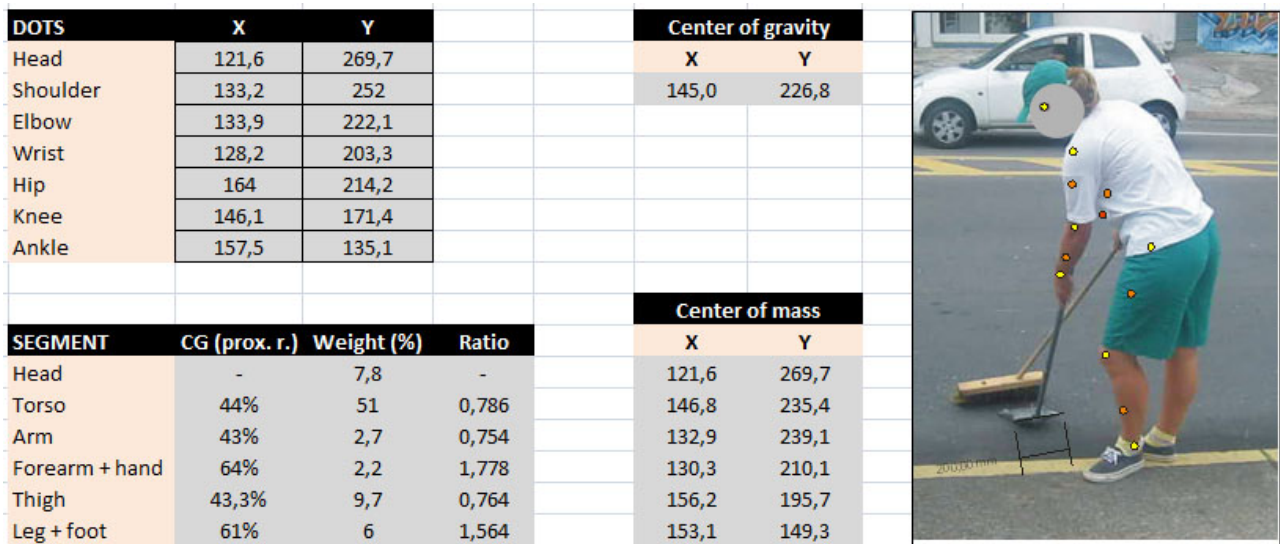


Figure 2 – Spreadsheet of calculation of the inertial properties of the second worker

A first conclusion obtained as per the study made is that the worker in question, on executing the procedure of collecting waste, in constant situations, is used to projecting her center of gravity towards the street that, in this case, is a busy avenue, running the risk of losing her balance. The image also confirms the difficulty of stability of the lower limbs at the edge of the pavement and the bad posture adopted when the shovel is lifted to put the waste in the trash can. It was

observed that both the functions exercised by the workers analyzed have critical aspects, related to the physical requirements of the working environment, which deserves deeper insight and actions for the implementation of improvements to the working environment in various aspects.

2.3 Analysis of the Activities

Finally, the phase of the Analysis of the Activities is made in an AET, in order to obtain more specific information and obligations of ergonomic recommendations based on what the worker actually does in their workplace. Thus, the Analysis of Activities “is what the worker effectively does to execute the task. It is the analysis of the behavior of a worker in their workplace (actual work)” (MERINO, 2008, p. 58). The activities effectively executed by each of the workers are the following:

- Worker 1:

1. Starts the job by sweeping small areas and piles up small quantities of waste so that the second worker can collect it;
2. Transports the broom manually to the next area to be swept during her course of work.

- Worker 2:

1. Moves to the small piles of waste, pulling the cart behind her, usually with the left arm, while holding the broom with the right arm;
2. On approaching the waste, she positions the cart on the pavement, removes the shovel from inside the cart and positions it close to the waste, while sweeping it on with the broom;
3. By placing all of the waste onto the shovel, she balances it with the broom, while suspending both instruments until reaching the opening of the recipient, at a height of one meter, approximately;
4. Finally, she inserts the shovel back into the cart and then transports the cart to the next pile of waste.

3. DISCUSSION ABOUT THE RESULTS

Besides the physical aspects required for the profession, already evidenced in this article, a series of mental and sensorial requirements related to the work of street sweepers were verified. Some of them are related to the concentration required for the correct execution of the work, like finding the dirt correctly, cleaning with efficiency and the attention required focused on the various elements existing in their workplace, like the constant traffic of vehicles and pedestrians. On cleaning the limits of the pavements and on crossing streets, the concentration required to avoid accidents is much higher. In addition, the attention required so that the whole region is swept and the material is transported appropriately was also evidenced with the mental and sensorial requirements related to the study in question. It is also important to highlight the fact that worker 2 transports the suspended broom with one of the upper limbs, while moving the cart with the other. There are also many critical aspects related to the working environment, like the level of noise, risks of traffic accidents and dealing with weather conditions and the geographical obstacles of the city.

Based on the exposure, the ergonomic recommendations resulting from the analysis presented can be summarized in two main aspects, which are: 1) Working on a rota of duties and; 2) Redesign and development of the equipment for a specific situation. For the first case, focused on the organization of the work, the initiative of creating a rota, or change of duties between both the sweepers will contribute towards relieving the load and the typical effort resulting from each activity executed. On executing two distinct activities in smaller intervals, these multi-functions

will benefit both the workers in the sense of avoiding injuries caused by repetitive effort and undesired stereotype effects. In relation to the second recommendation, a former proposal in an article by Nickel *et. al.* (2009) was consulted, in which there are lists of the obligations resulting from this ergonomic analysis, envisaging the development of new equipment for the job, more adapted to the requirements of the working environment analyzed. On the other hand, the focus of this article was to disseminate in detail the stages involved in the present AET and the application of the two tools already present in distinct postural circumstances.

4. FINAL CONSIDERATIONS

This research – based on specific knowledge of the areas of Ergonomics and Biomechanics – provides subsidies for the continuous improvement of the physical ergonomics of the working environment of street sweepers in the city of Florianópolis, focused on the study of the movements performed by the worker. The results of the AET made, conducted and guided modifications to improve the working conditions. The critical aspects were evidenced and, through the recommendations proposed, were used to improve the productivity and quality of the service provided by the workers analyzed.

The contribution of this study became clear, on diagnosing and presenting recommendations for the correct dimensioning and organization of the working environment of street sweepers. These recommendations have been from small adjustments in the organizational structure in which the profession is inserted to the emphasis on ergonomic aspects related to the form, dimension, handles, weights, materials, and everything that enables the productivity and quality of the service and usage, mainly related to the user.

5. REFERENCES

- [Guérin01] GUÉRIN, F. *et. al.* Compreender o trabalho para transformá-lo: A prática da Ergonomia. São Paulo: Edgard Blücher, 2001.
- [McAtamney93] McATAMNEY, L. e CORLETT, E. N. Rula: a survey method for the investigation of work-related upper limb disorders. In: Applied Ergonomics. Vol. 24(2), p. 91-99: Butterworth-Heinemann, 1993.
- [Merino08] MERINO, E. Ergonomia. Florianópolis. Universidade Federal de Santa Catarina. 2008.
- [Nickel09] NICKEL, E. M. *et. al.* Ergonomia e Biomecânica como base no desenvolvimento de novos produtos: o caso do equipamento para recolhimento de resíduos urbanos. In: 9º ERGODESIGN - Congresso Internacional de Ergonomia e Usabilidade de Interfaces Humano-Tecnologia: Produto, Informações, Ambiente Construído e Transportes. Curitiba-PR: 2009.
- [Riehle79] RIEHLE, H. Die biomechanik der wirbel saule beim trampolinturmen. Sankt Augustin: Verlag Hans Richarz, 1979.
- [Signori04] SIGNORI, L. U.; GUIMARÃES, L. B. M. e SAMPEDRO, R. M. F. Análise dos instrumentos utilizados para a avaliação do risco da ocorrência dos D.O.R.T./L.E.R. In: *Produto e Produção*, vol. 7, n. 3, p. 51-62, out. 2004.
- [Vasconcelos08] VASCONCELOS, R. C. *et. al.* A estratégia de “redução” e a carga de trabalho dos coletores de lixo domiciliar de uma grande cidade: estudo de caso baseado na Análise Ergonômica do Trabalho. In: *Revista Brasileira de Saúde Ocupacional*, São Paulo, 33 (117): p. 50-59, 2008.