PROPOSAL OF A MODEL OF ERGONOMIC RISK ANALYSIS TOOL ON VISUAL INSPECTION WORK STATIONS IN THE AUTOMOTIVE INDUSTRY

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Abstract. *The increase of retirement rates of employees caused by work-related musculoskeletal disorders (MSD) has driven the companies to take some drastic actions in order to combat the main causes of these diseases, especially when it comes to existing workplaces. One way of accomplishing this task in a short lead time, consists on mapping the ergonomic risk of all workplaces within the company and so, by a priority analysis, concentrating efforts on workplaces with high ergonomic risks, which someday could become an occupational disease source, increasing the absenteeism, as well as the costs of health administration department and bringing down the motivational environment. The difficulty of mapping a workplace is not only the data survey but also its treatment and evaluation in order to allow us taking the correct decision when it comes to priorities. The aim of this article is to research and suggest a model of an ergonomic risk analysis tool that takes into account the existence or absence of some specific job factors and, additionally establishes a risk ranking scale for each specific condition observed in a specific workplace. This tool will provide technical subsidies for the decision whether a workplace must be totally modified for having several small ergonomic problems, which could bring out ergonomic risk, or if only some specific items must be improved for being focus of a high ergonomic risk. At present these latter items are being relatively hidden by the use of the existing checklists and are not clearly presented in the final results. This model has been tested in many visual inspection workplaces at automotive companies where enough information about existing and non-existing ergonomic problems is available. Based on this it was possible to set the ranking scale needed to the technical validation and the practical applicability of the model.*

Keywords. *Ergonomics, Checklist, Ergonomic Risk Analysis*

1. Introduction

The technological changes and the new techniques on business management have caused various alterations on methods and production processes. To keep up with these changes, it is necessary to offer the employees/collaborators appropriate conditions so that they can perform duties and activities comfortably and safely. Thus, it is necessary to project working posts and organize production systems with an ergonomic concept in mind.

From the premise that, the achievement of quality in products or services and the rise in productivity, will only be possible with life quality at work, the ergonomic project of working posts and production systems are not only a necessity of comfort and safety but, a strategy for companies to survive in the globalized world.

The safety and medical professionals at work, (work safety engineers, work-related doctors, safety technicians, work-related nurses and occupational hygienists), must permanently be aware, capable and qualified to utilize The Ergonomic Technology in all its plenitude (multi-disciplinary and range), so as to offer the entrepreneurial and governmental organizations, means to ergonomically adequate working conditions at work, as a way to provide higher life quality at work in industrial as well as in administrative environments.

Productivity and quality in products or services, is directly linked to the working post and productive systems, and these, must be ergonomically appropriate to the workers/collaborators, so that they can perform their duties comfortably, efficiently and with efficacy, without causing any harm to the physical, psychological and cognitive welfare of professionals.

The future of organizations will depend, more and more on creativity and participation of employees in finding solutions to problems and this will only be possible if the working environment is ergonomically appropriate.

What we have noticed in the majority of Brazilian companies, particularly the companies in the industrial sector, is a complete disregard towards working conditions and consequently, to life quality of employees/collaborators. Only in a few multinational or transactional companies, as they are being denominated today, and in some national companies, ergonomics is being utilized as a tool to improve efficiency and efficacy of employees/collaborators at their working posts.

In this article we have tried to primarily show the history and evolution of ergonomics, its importance today and the future, as well as the evolution of approaches towards ergonomics projects at working posts and the specific range of each project with their particular focus. As the approach, we have sought to develop a tool, which would serve as a basis for fast assessment of ergonomics risks and the decision-making of which working posts would have to be improved and their urgency. The proposed checklist model seeks to fill the gap left by other checklists in terms of insensibility in detecting ergonomics risks, a situation when the working post only has one non-ergonomic point, being regarded as a critical point and with high risk to cause the employee RSI/DORT, or when they have various deficiencies, apparently not relevant, but which are likely to become the cause of occupational injuries.

2. Ergonomics and Productivity

It is the study of adaptation of man at work (Iida, 1990), as a matter of fact, it deals with multidisciplinary studies, as it utilizes knowledge of various scientific areas as, for instance, medicine, engineering, psychology, business management, etc. For Couto (1995) ergonomics "is a group of sciences and technologies which aims at the comfortable and productive adaptation between the human being and their jobs, basically seeking to adapt their working conditions to human characteristics". Besides theoretical discussions, ergonomics is also defined in a specific legislation. The decree 3.751 of 23/11/90 of the Work Ministry refers to NR 17 Ergonomics. This norm "seeks to establish parameters which enable the adaptation of working conditions to the psycho-physiological characteristics of employees, so as to provide maxim comfort, safety and efficient performance. Working conditions include aspects related to lifting, shipping and unloading of materials, from furniture to equipment and also environmental conditions of the working post and the organization of tasks themselves. To assess the adaptation of working conditions to the psycho-physiological characteristics of employees, it is up to the employer to run the ergonomics analysis at work, which should treat, at least, working conditions as established in standard regulations.

Formally, the term productivity was utilized for the first time by Quesnay in 1766. The European Community defined productivity in 1950, as "the quotient obtained by the division of output by one of the factors of production" and Schoeps (1990) defined total or global productivity as the quotient between the production and resources used. Many times a global productivity calculation, for example, revenues divided by total costs, could be important to strategic decision-making, although it does not allow visualizing positive and negative points within the organization. It is necessary to work out the calculation and take other factors into account. This is called partial productivity. Martins and Laugeni (1998) defined partial productivity as "the relation between the output, measured in a particular way, and the consumed of the utilized resources." Specifically in this work, it was evident that labor productivity, which according to the same authors is "the relation between the total output in the period, at constant costs, and the total input of labor in the same period, at constant costs." For Schoeps (1990) it is the "production of physical units divided by the total number of man per hour." Productivity and ergonomics are closely related, as the natural consequence of a dimensionally ergonomic working post is higher job satisfaction, higher disposition for work and fewer absences or health leaves. The outcome leads to higher productivity of the employee and a reduction in costs for the company.

3. Ergonomics Risk Analysis

According to Sander and McCornick (1993, p. 678) "It seems that many accidents occur because people do not identify or underestimate the danger or the risk involved in a situation or course of action."

The activity risk analysis subdivides the function performed at working posts in various elements or actions, describing, and at times, quantifying the risk factors inherent to these elements and identifying the conditions, which contribute to these factors (Putz-Anderson 1988; Keyserling et al. 1993). Different factors influence the perception of risk: objectively, as for example, the conditions of the sensorial system and the length of working experience (Wickens, Godon and Liu 1998), and subjectively, such as the acceptability and exposure to the risk (Guilam, 1996). As the subjective aspects present variability, even among the individuals of the same population, it is important to access them in the context in which they are inserted. Despite the complexity of the issue and the fact that it has never been deeply studied, an analysis of this type, is fundamental, as the perception of risk influence the behavior and the degree of action precautions of the individuals facing situations which could cause lesions and accidents (Sanders and McCornick, 1993).

As regards the perceptions of signs, some tasks results in embarrassment in the process of information, which comes before the decision making. Therefore, the execution of the task implies much attention and obedience to the prescribed procedures and attentiveness is a limited skill of humans. (Wickens, Gordon and Liu, 1998). Macro-ergonomics in the working environment (Guimarães, 1999), which foresees the survey and data analysis with the direct and indirect participation of the users.

4. Methodology of Tool Validation

The present paper resulted from the idea of creating a checklist model, which could be utilized, in ergonomic assessments in a fast and efficient way. The objective of such checklist is not to evaluate the operational task in detail, but to search for evidence, which indicate the need for changes, either fast or not, in the working post. Intending, thus, to reduce the risk of occupational injuries to the minimum, determining a grading of actions to be taken by the responsible ones. Furthermore, there is some intention to introduce an analysis of critical points of the working post, because the present checklists tend to sum up scores and be sensitive only when the post has various negative points. The practical experience give some evidence that some of the health leaves due to occupational injuries are resulted from only one negative point in the working post, as is the case in the spare parts visual inspection, where the lack of arm rests can cause injuries to the employee, even if the remaining area of the post was ergonomically projected. This was one of the reasons such working post has been chosen to be studied.

Basing on this restriction, two sources of checklists available in literature were searched through and attempt was made to adapt them to the practical experience acquired in the assessment of posts where there have been complaints from workers about pains, with or without health leaves, and where the nexus causal between the pain and the task had been confirmed. The remaining analyses (18) were executed in improved working posts, where there has been no report of the reoccurrence of complaints, or in posts where there has never been a complaint from the workers. Applying the checklist in these working posts, there have been individual and accumulated punctuations, resulted from the addition of the punctuation of the individual items, which have been assessed through the average rate and the Normality of the data. From this result we sought to answer the following questions: (a) is the checklist sensitive to specific ergonomic problems? Is the checklist sensitive to existing situations of various ergonomics problems in the same working post? (c) does the checklist bring results, which enable to analyze the ergonomic risk and indicate the urgency of decision-making by the ones in charge?

Having answered these questions positively, the final format of the checklist was made, with the objective of making it more practical and easier to be utilized. It can be printed on paper within the working post and also in personal computers in spreadsheet format, where the punctuations and the results are shown automatically as the data is inserted, allowing even the simulation of proposal for future improvements.

5. Proposed Models

The proposed model (picture 1) presents the following characteristics:

(a) Header – containing fields for general data about the company, the department, the employee, the product, the operation, the date, etc, and a field for the description of the task;

(b) Body, containing a list of 36 activities likely to be executed by the workers, the detailed description of the activity so that the scope is clear, 5 columns of grading of the frequency of the execution of the tasks with the respective punctuations (never/not apply (0), almost never (1), sometimes (5), many times (8), always (10)), one column with the weight for each activity and, finally, a column with the total punctuation for each activity (weight x activity punctuation);

(c) Footer, containing the analysis summary: 1-Total punctuation, 2 – Punctuation of the items which "always" happen and 3- Punctuation of the critical items, which are those that when present in the maximum category ("always") should spark off an immediate action, because its ergonomic risk is high. Furthermore, there is also information regarding the grading of the ergonomic risk and the respective grading of the urgency of decision-making.

The frequencies of the execution of the tests were given punctuations varying from 0 to 10, as above described, to offer 5 alternatives to the user of the checklist and so to permit an analysis without the need of very precise information. These punctuations were tested by the application of the checklist and analyzed later in chapter 6.

The weights were conceived to permit a clearly separation of the more critical, risky activities from those less critical and risky. By multiplying the punctuation of the frequency of an activity with the respective weight the result is supposed to be sensitive enough show the ergonomic risk.

Finally, the sum of the punctuations was studied and a criterion of risk classification was determined based on the practical experiences described below. It must be emphasized that the use of the same criteria of other existing checklists, for example RULA and OWAKO, was not recommended due to the different conditions and range used in this study.

6. Results and Conclusions

As previously mentioned, the checklist model was applied in 22 working posts of visual inspection with evident ergonomics problems and in 18 ergonomically improved or without any ergonomics risks working posts. The results are plotted in picture **(**2**)**.

The group of points in the shape of diamonds refer to the non-ergonomical working posts and it is the result of the punctuation obtained through the addition of the punctuation multiplied by the respective weights (in the checklist these values appear in the footer as "1 = total punctuation"). The average found was 215 points and the standard detour was

52,55. Applying the Gaussianidade based in the normal probability plot, symmetric indexes and curtose between 2 and –2, which indicates that the results are Gaussianos.

UFPR	**Checklist for the ergonomic risk assessment**								**Sheet.**	**of**
	on visual inspection workplaces								**Date:**	
Company:		**Worker's name:**							**Worker's number:**	
Product:		**Operation:**							**Machine:**	
Department:		**Assessor:**								
Task Description:										

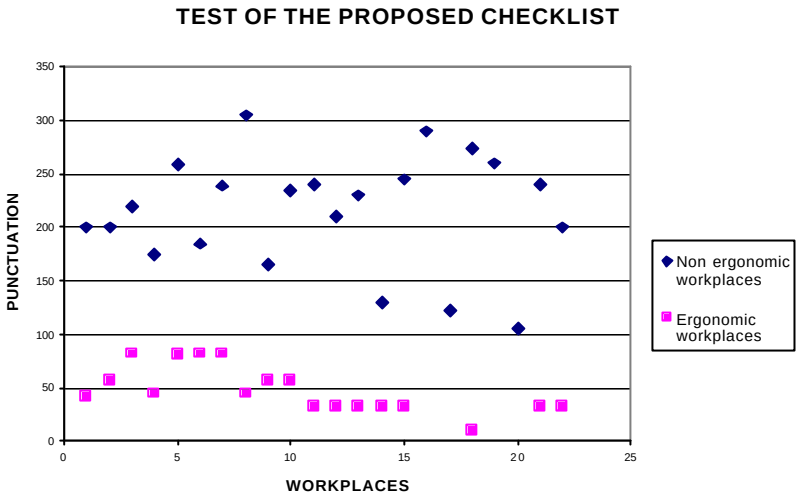
N°	Activity	Details	Never / not appliable	Almost never	Sometimes	Many times	Always (in the takttime)	grade	Total (grade x punctuation)
		Punctuation	0	1	5	8	10	X	X
1	Standing-up work	no chair available						1	0
2	Sitting-down work	chair not ergonomic						2	0
3	Trunk position	static and bent forwards						5	0
4	Trunk position	static and without chair rest						5	0
5	Need to lift objects from the floor							5	0
6	Turn trunk to reach objects	without turning the chair or body						5	0
7	Carry weight	1 to 5 kg (ref. NIOSH standard)						2	0
8	Carry weight	6 to 23 kg (ref. NIOSH standard)						5	0
9	No foot rest	or without adjustment						3	0
10	Forearm are kept in static position	without arm rest						5	0
11	Forearms are kept lifted far from the body	without arm rest						5	0
12	Forearms are kept lifted higher than the heart							5	0
13	Forearms are kept rested	on sharp edge of the table						5	0
14	Forearms are lifted above the shoulders							5	0
15	Inspect objects weighing more than 1kg	without armrest						5	0
16	Turn objects weighing more than 1kg	without armrest						5	0
17	Fingertips used to grasp objects	with appliance of force						5	0
18	Inspect sharp edged objects (risk of injury)	without gloves						5	0
19	Inspect inside of bores without instrument							2	0
20	Inspect outside of parts without instrument	1 mm of diameter or less						3	0
21	Random inspection of parts	without standard method						2	0
22	Feasts are kept in a forced position							5	0
23	Workplace ilumination of less than 500 lux	or excess of ilumination						3	0
24	Head is kept bent to the front	angle of 30° or more forwards						5	0
25	Working bench height not correct	< 900 or > 1100 mm						2	0
26	no shift of tasks among workers	repetitive and tiresome tasks						5	0
27	Takt time less than 30 seconds							5	0
28	Takt time from 30 to 60 seconds							2	0
29	No practice labor gymnastic							2	0
30	Worker has a history of occupational desease	in other workplace						3	0
31	Worker has a hobby envolving manual work							2	0
32	Worker is under productivity pressure							5	0
33	Head position is too high	from the horizon line up						5	0
34	Trunk has to be bent from chair lane during the task	to reach objects or switches						3	0
35	Apply of force with forearms or fingers	perceptive effort						5	0
	TOTAL	TOTAL	0	0	0	0	0	X	0

Results:	Ergonomic risk assessment: midium risk = action needed!	High risk = Immediate action!
1 - Total punctuation: 0	Result: from 100 to 150 = medium risk	> 150 = high risk
2 - Punctuation of the items that happen ALWAYS (10 pontos): 0	from 10 to 39 = medium risk	> 39 = high risk
3 - Punctuation of the critical items (sum of the points of critical items in column ALWAYS): 0		>10 = high risk

Picture 1 – Proposed Checklist

The group of points in the shape of squares refer to the working posts considered ergonomically appropriate and it is the result of the punctuation obtained by the addition of the punctuations of the activities multiplied by their respective weights (in the checklist this values are shown in the footer as "1 – Total Punctuation"). The average found was 48 points and the standard detour was 21,8. Applying the Gaussianidade test based on the normal probability plot symmetric and curtose indexes were found between 2 and –2, which indicates that the results are distributed according to the Gauss Curve.

It can be clearly noticed that there is a gap in the plot between the punctuations of ergonomical and those of non-ergonomics posts, making it evident that it is possible to distinguish them with the application of the checklist model.

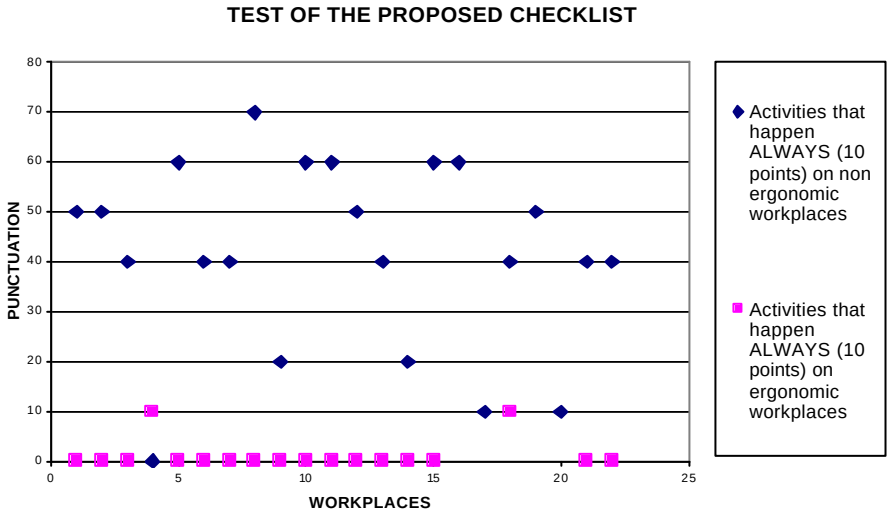


Picture 2 - Results

Thus, based on the previous plot, limits from 0 to 99 points have been established and characterize low-risk working posts, from 100 to 150 points for the high ergonomical risk working posts, which demand an immediate action.

The question "(b) is the checklist sensitive to various ergonomical problems present in the same working post?" was given a positive response with the use of the checklist. This punctuation is shown in the footer of the checklist mode, in the same line as the "Total Punctuation".

Similarly, the points were obtained by the addition of all the punctuation related to the frequency option of "Always" (10 points). The results acquired are shown in picture (3).

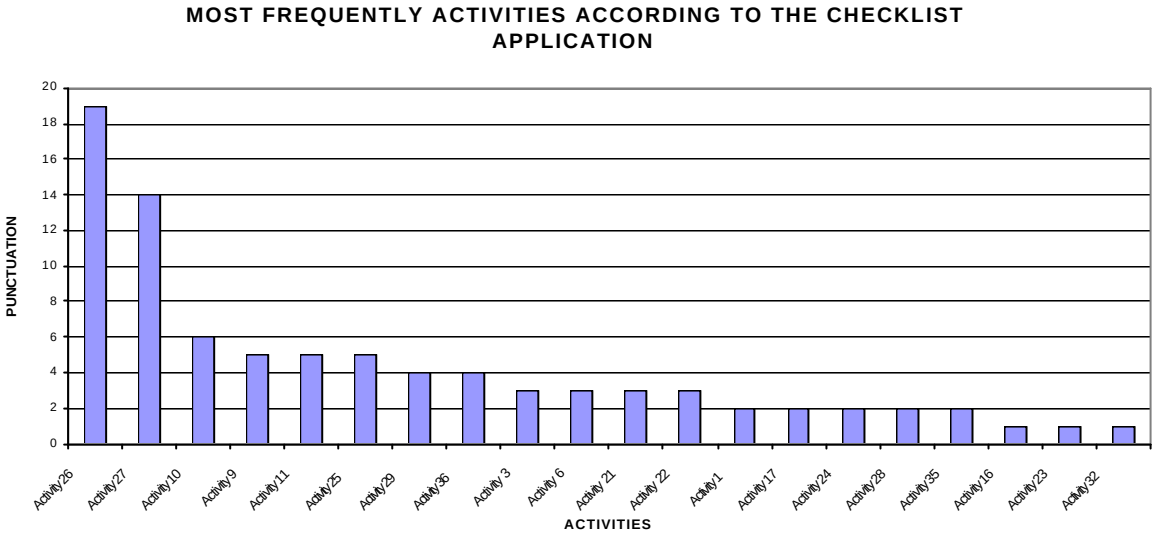


Picture 3 - frequency option of "Always"

Additionally it was sought to locate and analyze the activities, which were shown with higher frequency in the assessment of working posts considered non-ergonomical. For this, the Pareto Plot was utilized (Picture 4).

Considering the frequency which these activities were present in the analyses in the checklist model, it was concluded that they are activities which are regarded as critical and they should have weight 5 in the checklist. Comparing to the weights attributed to them, it was noticed that 4 activities presented weight 4 and one, activity 4, had an inferior weight, that is, 3 and the correction of weight of these 4 activities was made in the checklist model. Because

they are critical, these activities, if put in evidence in an ergonomical assessment, should always generate correction actions, because they possess high ergonomical risks. For this to become evident in the application of the checklist model, a third analysis was introduced, the analysis of critical activities. It is the addition of the points in every activity, which are shown in the footer of the checklist model as "3 – Punctuation in the critical items (addition of the critical points in the column ALWAYS)". In this case the evidence of one of these activities with the ALWAYS frequency and the maximum punctuation of 10 will be shown as the activity of high risk in this field in the footer and will indicate that an immediate action should be taken. In the checklist model the frequency fields ALWAYS in the critical activities were highlighted from the others by using a thicker border.



Picture 4 – Pareto Plot

This way the question "(a) is the checklist sensitive to specific ergonomical problems?" was given a positive response with the use of the checklist model.

As regards the third question: "(c) does the checklist bring a result which could analyze the high ergonomical risk and indicate the urgency of decision-making by the ones in charge?, this question will be responded positively by the information shown beforehand. In the footer of the checklist model, the risk analysis is indicated (low, medium, high) and the need for actions of corrections in the working post is present.

According to the results of the tests, the evidences raised and the corrections done, the punctuations, weights and risk classification defined in chapter 5 seem to be good and sensitive enough and the checklist model proved to be an efficient tool for the ergonomic risk assessment in the working places of visual inspection.

Based on this study, it is possible to test the checklist in the future on other working places, aside from visual inspection, in order to make it a wide-rang tool in companies of the automotive industry.

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