Dealing with ergonomic risks in industrial settings

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Dealing with ergonomic risks in industrial settings

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SUMMARY

Musculoskeletal injuries are a problematic issue worldwide. In Europe, musculoskeletal injuries represent up to 40% of labour compensation and are responsible for up to 1.6% loss in the GDP. Because ergonomics is one of the key solutions to this problem, many companies around the globe employ ergonomic concepts in their production processes. However, the development of ergonomic projects within Latin American companies is a major challenge because although some employees and employers have some knowledge of ergonomics, there is still a lack of knowledge among them.

In the case of Brazil, ergonomics is applied in many industries due to the fact that there is a law (Regulatory Standard NR-17) established by the Ministry of Labour and Employment. This standard contributes a great deal to a favourable scenario for ergonomics in the country. Having said that, there is also a discouraging condition for the field of ergonomics in Brazil, namely, the way ergonomic services are offered. In some instances, ergonomics professionals refrain from considering fundamental particularities of the work environment of the company such as corporate culture and the view of the production process as a whole.

A solution for embedding ergonomics in the culture could be the macroergonomics approach as it has been shown beneficial in previous years and as proposed by Hendrick and Kleiner. A macroergonomics approach includes analysing and designing work processes and organizational elements leading to organizational effectiveness and safety by looking at the whole system. This framework was applied in this PhD to deal with ergonomic risks in different industrial settings and segments. This new view of managing ergonomic risks enables continuous ergonomic improvements by involving a multidisciplinary team in companies.

This approach includes a multidisciplinary team involved in the identification and management of ergonomic risks as well as in the development of practical ergonomic solutions, in a systematic manner.

In this PhD the macroergonomic approach was applied and the applications showed that it is possible to apply it in Brazil and any company in the world. It resulted in other behaviour and ergonomic improvements and a culture where ergonomics is embedded in the management and in the activities of the employees. It took quite some effort and patience (4 years), but this is described in the literature as well.

The thesis is outlined as follows:

Chapter 1 - consists of a literature overview showing the potential of a macroergonomic approach and participatory ergonomics and using practical assessment like RULA. The question is whether this approach would also work in Brazil, which is studied in this PhD.

Chapter 2 - examines ergonomic risks and alerts for the failure to include them in homogeneous exposure groups (HEGs). It also presents a survey that shows the lack of common understanding of the topic and consensus among professionals in the area of Environment, Health and Safety (EHS). This chapter shows that, for ergonomics, a homogenous group approach does not work. For instance, back complaints can be found in a homogenous group, but the intervention and the ergonomic risk are totally different for an office worker and for a person lifting objects working in the same space.

Chapter 3 - addresses ergonomic management and shows the importance of involving management and other representatives of the company in ergonomic committee. It also proposes new approaches which integrate several areas (occupational medicine, engineering, work safety, legal area, among others) of the company involved with the work and the worker for a successful ergonomics programs.

Chapter 4 - shows that workers performing the same task can adopt different postures and ways of working. Such differences may lead to positive or negative impacts on ergonomic risks, which could compromise the worker's health and the quality of the production process. Therefore, it is important to study individual behavior while working and not only implement general improvements.

Chapter 5 - presents some successful ergonomic solutions using participatory ergonomics to eliminate or prevent musculoskeletal complaints. Involving employees in the improvement process creates better ideas, as well as increases the chance of adoption. In addition to that, chapter 5 shows that the program should be linked to other initiatives in a company like Lean Manufacturing, which is a characteristic of the macroergonomic approach.

Chapter 6 - is an overall evaluation of this PhD, whose research question concerns the challenges that are faced in dealing with ergonomic risks in different industrial settings in a practical way. In the cases described in this PhD thesis it is shown that there are many challenges. It also shows that a 20+year-old approach described in the introduction of this PhD called macroergonomics and participatory ergonomics are still valid. Elements of these approaches described in the literature

seem to be validated as well by the cases in this PhD. Elements like 'start with smaller interventions focused on musculoskeletal problems', 'involve stakeholders', 'also focus on increase of productivity', 'work towards a company-wide approach' and 'embed it in the culture of the company' are shown to be important.

SAMENVATTING

Aandoeningen van het bewegingsapparaat zijn een wereldwijd probleem. In Europa vertegenwoordigt letsel van het bewegingsapparaat 40% van de arbeidsongeschiktheid en 1,6% verlies aan BNP. Ergonomie is een van de sleuteloplossingen voor dit probleem. Daarom maken bedrijven wereldwijd gebruik van ergonomische principes in hun productieprocessen. In Latijns-Amerika is de ontwikkeling van ergonomische projecten echter een grote uitdaging want, hoewel sommige werknemers en werkgevers enige kennis van ergonomie hebben, is er bij hen een gebrek aan kennis.

In het geval van Brazilië wordt ergonomie toegepast in veel sectoren, doordat het Ministerie van Werk en Werkgelegenheid een wet heeft ingevoerd (Regeling Norm NR-17). Deze regeling draagt veel bij aan een gunstig beeld voor ergonomie in Brazilië. Dat neemt niet weg dat er ook een ontmoedigende omstandigheid is op het terrein van ergonomie in Brazilië, namelijk de manier waarop ergonomische diensten worden aangeboden. In sommige gevallen laten beroepsergonomen achterwege de fundamentele aspecten van de werkomgeving van het bedrijf in ogenschouw te nemen, zoals de bedrijfscultuur en de kijk op het gehele productieproces.

Een oplossing voor het integreren van ergonomie in de cultuur kan worden gevonden in de macro-ergonomische benadering van Hendrick en Kleiner, die in de afgelopen jaren zijn waarde heeft bewezen. Een macro-economische benadering omvat de analyse en het ontwerp van werkprocessen en organisatorische elementen, die leiden tot organisatorische effectiviteit en veiligheid door naar het gehele systeem te kijken. Dit kader is in deze PhD toegepast op de ergonomische risico's in verschillende industriële omgevingen en sectoren. Deze nieuwe kijk op het beheersen van ergonomische risico's maakt voortdurende ergonomische verbeteringen mogelijk door de betrokkenheid van een multidisciplinair team binnen bedrijven.

Deze benadering omvat een multidisciplinair team dat betrokken wordt in de vaststelling en beheersing van ergonomische risico's, alsmede in de ontwikkeling van praktische ergonomische oplossingen op een stelselmatige manier.

In deze PhD is de macro-ergonomische benadering toegepast en de toepassing heeft getoond dat het mogelijk is deze in Brazilië en in elk bedrijf ter wereld toe te passen. Het heeft geresulteerd in gedragsverandering en ergonomische verbeteringen en een cultuur waarin ergonomie is geïntegreerd in het management en in activiteiten van werknemers. Het heeft veel moeite en geduld gekost (4 jaar), maar dit wordt ook in de literatuur beschreven.

De thesis is als volgt opgebouwd:

Hoofdstuk 1 - bevat een opgave van het potentieel van een macro-ergonomische benadering en ergonomie op basis van medezeggenschap van de werknemers en met gebruik van praktische evaluaties zoals RULA. De vraag die in deze PhD is bestudeerd is of deze benadering ook zou werken in Brazilië.

Hoofdstuk 2 – onderzoekt ergonomische risico's en signalen over het niet-opnemen ervan in homogene risicogroepen (EHS). Het bevat ook een onderzoek dat het gebrek aan gezond verstand over het onderwerp en eensgezindheid onder deskundigen op het gebied van milieu, gezondheid en veiligheid aantoont. Dit hoofdstuk toont aan dat een homogene groep benadering niet werkt voor ergonomie. Bijvoorbeeld, rugklachten kunnen voorkomen in een homogene groep, maar de maatregelen en ergonomische risico's zijn geheel verschillend voor een kantooremployé dan voor een persoon die in dezelfde ruimte zware objecten tilt.

Hoofdstuk 3 – behandelt het management van ergonomie en toont het belang van het betrekken van management en andere vertegenwoordigers van het bedrijf in ergonomie-comités. Het doet ook voorstellen over nieuwe benaderingen voor een succesvol ergonomie programma, die verschillende vakgebieden van het bedrijf integreren (o.a. arbeidsgezondheidskunde, (werktuig)bouwkunde, veilig werken en juridisch), die betrokken zijn bij het werk en de werknemer.

Hoofdstuk 4 – genaamd Werkverbeteringen, toont aan dat werknemers die dezelfde taak uitvoeren verschillende houdingen en manieren van werken kunnen aannemen. Zulke verschillen kunnen tot een positief of negatief effect op de ergonomische risico's leiden, hetgeen nadelig kan zijn voor de gezondheid van de werknemer en voor de kwaliteit van het productieproces. Het is daarom belangrijk individueel gedrag op het werk te bestuderen en niet alleen algemene verbeteringen te implementeren.

Hoofdstuk 5 – biedt enkele succesvolle ergonomische oplossingen met gebruik van ergonomie op basis van medezeggenschap van het personeel bij het voorkomen van klachten over het bewegingsapparaat. Het betrekken van werknemers in het verbeteringsproces leidt tot betere ideeën, maar het verhoogt ook de kans op acceptatie. Daarnaast toont hoofdstuk 5 dat het programma verbonden moet zijn met andere initiatieven in het bedrijf, zoals Lean Manufacturing, wat een kenmerk is van de macro-ergonomische benadering.

Hoofdstuk 6 – is een algehele evaluatie van deze PhD. De onderzoeksvraag van deze PhD betrof de uitdagingen die worden ervaren in het omgaan met ergonomische risico's in de praktijk in verschillende industriële omgevingen. In de gevallen die in dit PhD proefschrift worden beschreven, wordt getoond dat er veel uitdagingen zijn. Ook wordt aangetoond dat een 20+ jaar oude benadering die in de inleiding van deze PhD wordt beschreven, genaamd macro-ergonomie en ergonomie op basis van medezeggenschap, nog steeds geldig is. Ook elementen van deze benadering die in de literatuur worden beschreven lijken te worden gevalideerd door de casussen in deze PhD. Het belang wordt aangetoond van elementen als 'Begin met kleine interventies gericht op het bewegingsapparaat', 'Betrek belanghebbenden', 'Focus op verhoging van de productiviteit', 'Werk toe naar een bedrijfsbrede benadering' en 'Integreer het in de bedrijfscultuur'.

CHAPTER 1

General Introduction

General Introduction

1

Industries all over the world have been modifying their production processes and labour relations due to either economic issues or technological transformations.

Amidst these changes, keeping productivity and high quality at competitive prices has become a challenging global objective. This is the case mainly in industrially developing countries, such as Brazil, China, India and Mexico. Globalization has both positive and negative effects (Zink, 2009). On the positive side, we can state that globalization generates employment opportunities and brings new technologies to the countries where industries are located. Concerning the negative aspects of globalization, however, there are the so-called *Export Processing Zones* (EPZs), where one will face the establishment of unattainable working goals as well as violations of labour and social laws and regulations, which are common practices among some multinational companies aiming at reducing production costs (ILO, 1998).

The EPZ concept should be understood as the one provided by the International Labour Organization (ILO): “Industrial zones with special incentives set up to attract foreign investment in which imported materials undergo some degree of processing before being re-exported” (ILO, 1998).

There seems to be a dichotomy between industrially advanced countries (IACs) and industrially developing countries (IDCs) (Scott, 2009). In IDCs, it is common for activities and tasks to be carried out in unsafe environments (McNeill et al., 2000) and without much consideration to ergonomic issues in the production process or in the work stations. One of the biggest problems worldwide in production facilities are the work-related musculoskeletal injuries due to poor working conditions (Larson, 2014). The layout of work stations that combines both ergonomics and ergonomic concepts in the productive process contributes to the prevention of work related musculoskeletal disorders (WRMSD), increases productivity and generates comfort and satisfaction to the worker (Miguez et al., 2017).

WORK-RELATED MUSCULOSKELETAL DISORDERS (WRMSD)

The term work-related musculoskeletal disorders (WRMSD) is used as an umbrella term to describe the several clinical forms of pains and discomforts that may affect the bones, joints and supporting structures of the musculoskeletal system, mainly in the upper limbs. They may occur due to the interaction of several labour factors such as: repetitive movements, awkward postures, static posture, vibration, intense exertion, handling heavy loads, long periods of work without pauses, psychosocial and individual factors, among many others (Nugent and Fallon, 2015). This way, organizational, biomechanical, psychosocial and individual factors must be taken into account in order to comprehend WRMSDs (Occhipinti and Colombini, 2016). These disorders are multifactorial in nature (Abaraogu et al., 2016) and, unlike common belief, they will affect workers of different functions and work activities both in industrially advanced countries (IACs) and industrially developing countries (IDCs).

THE COST OF WRMSD AND THE SOCIAL PROBLEMS

In Switzerland, the costs associated with WRMSDs are about 7.5 billion dollars a year. In other European countries, they represent up to 40% of labour compensation and are responsible for up to 1.6% loss in the GDP. It is estimated that the direct costs associated with a WRMSD case is approximately 35,000 to 40,000 euros (Occhipinti and Colombini, 2016).

The parts of the body usually affected by WRMSD are the shoulders, followed by the wrists, hands and elbows. Statistics show that 33% of workers with shoulder problems take longer to go back to work (Bongers, 2009). The results of a master's thesis reveal that the 76 male participants of the study - from different areas of a chemical company, employed over 36 months, performing the same task and with a significant number of monthly overtime hours - are 4 times more likely to develop WRMSDs than those workers who have been at the company for less than 36 months (Miguez, 2005). In other words, the time of exposure to the activity is a significant contributing factor to the development of WRMSDs (Miguez, 2005). Therefore, WRMSDs have economic impacts on society, workers and employers. By bringing discomfort to the worker, these disorders interfere in the quality of life and increase the number of sick leaves. They also increase absenteeism, promote low performance and reduce productivity. Both in industrially advanced countries (IACs) and industrially developing countries (IDCs), this scenario is attributed to poor working conditions (Rinaldo and Selander, 2016), be they physical, cognitive or organizational.

Sometimes, the WRMSDs cause a split in the labour relations and consequently bring about dissent within the labour environment which will, in turn, lead to labour lawsuits. Studies in Canada have reported that the number of labour lawsuits has been going up each year (Desmeules et al., 2016) and the same has been happening in Brazil. As an example, one could mention the 38,000 of indemnity paid to workers suffering from occupation herniated disk ("Trabalhador ganha indenização", 2017).

The Occupational Safety and Health Administration (OSHA) states that each year U$20 billion are spent on labour compensation related to injuries and diseases caused by ergonomic problems (Mani et al., 2016). According to a systematic literature review, there is still no consensus within the methodologies of study about the incidence and prevalence of musculoskeletal disorders (MSDs) with the factors of occupational risks. The methodologies that clarify issues related to this theme are rare, making it hard to establish a clear relationship between risk factor and WRMSD (da Costa et al., 2015). However, these methodological difficulties are understandable, since there are many variables influencing the WRMSD. These variables may include age, gender, period of work in the company, work movements adopted by the worker to perform a task and conditions of the workplace (Miguez et al., 2016). In view of that, assessing the work environment under a macroergonomic perspective is of paramount importance. According to Guérin et al. (2001), one must "understand work in order to transform it".

WORK ENVIRONMENT: A MACROERGONOMIC PERSPECTIVE

It is a fact that studies about the worker in his work environment have been carried out for quite some time. In 1957, a symposium entitled "Fitting the job to the worker" was held in Leiden, the Netherlands and, in 1959, an article was published with the same theme (Brown, 1959). Around sixty years have gone by and the theme of that symposium remains current; moreover, society is expecting more complete answers provided by the field of ergonomics.

As stated by Falzon (2014), in order to bring answers to the world of work in the 21st century, ergonomists can no longer be limited to just adapting the work to the worker, neither should they restrict themselves to looking solely at physical ergonomics. A more holistic view is necessary, where physical, cognitive, and organizational ergonomics are considered simultaneously (Occhipinti and Colombini, 2016) alongside with other factors that can positively impact both the health of the worker and the production process in a company. This way, the methodology of macroergonomics meets the aspirations of ergonomics for a more global and deepened vision within the world of work. According to Hendrick and Kleiner (2002), macroergonomics is the perspective, methodology, and subdiscipline of ergonomics that prioritizes the technology of human-organization interface. The goal of macroergonomics is to optimize work systems, including the participation of those involved (empowerment) in the several hierarchical levels, enabling continuous improvements in the production process.

Under a practical perspective, macroergonomics can be understood as: 1. *top-down* - since it requires the involvement of the company's board of directors; 2. *bottom-up* - because it is of a participatory character, and 3. *middle-out* – with a focus on the production process (Guimarães, 2004).

PARTICIPATORY ERGONOMICS

Because it has produced extremely satisfactory results, participatory ergonomics (PE) is the most commonly used approach in the macroergonomics field (Guimarães, 2004). It has, therefore, assisted in the dissemination of the field of ergonomics in a great deal of companies. The concept of participatory ergonomics is proposed by several authors in different ways and there does not seem to be a consensus (Wilson and Haines, 2006); however, these different definitions end up complementing each other.

Participatory ergonomics can be understood as a macroergonomic approach that requires the involvement of workers in the implementation of new technologies in the organizational system (Imada, 2002). It also calls for the involvement of people from different areas of the company in planning or re-planning their work activities; these people possess enough technical and scientific knowledge to influence the production process so the desired results can be achieved (Wilson and Haines, 2006). According to Vink et al. (2006), participatory ergonomics is the discipline that studies how different areas of knowledge are involved with the common goal of adapting work environments to humans during a design process. The literature points to several examples of the contribution of ergonomics to the improvement of job design (Larson et al., 2014), its results in the prevention and/or reduction of WRMSDs and consequent increase in productivity. As an example, we can mention a study in a metallurgical industry where an ergonomic intervention in the design of the production flow based on participatory ergonomics and lean manufacturing methodology resulted in a 33% increase in productivity in the finished good and a 50% reduction of piece handling, eliminating 100% of the ergonomic risks (Miguez et al., 2017).

These results show that it is possible to integrate productivity, quality, cost reduction, safety and health. This integration becomes ever so stronger and more efficient for employees and employers as ergonomic concepts are applied throughout the production chain (Caroly et al., 2016).

ERGONOMIC MATURITY

Implementing ergonomics comprehensively from the beginning to the end of a production process poses as a considerable challenge and is usually only possible when the company reaches ergonomic maturity. According to Vidal et al. (2012), the classic concept of maturity comes from psychology and was incorporated into the sub-discipline of project management taught in engineering courses. Inside the field of project management, the term "maturity" refers to the measurement of the capacity to promote change in an organization. On the other hand, within the field of ergonomics, maturity can be understood as a tool which aims to measure the scope of ergonomic actions in companies, ranging from the introduction and development to implementation and if these actions are sustainable.

The definition of sustainable actions becomes pertinent as we analyze the path that ergonomics has taken inside corporations, some of which will reach ergonomic maturity and others will not. According to Kerzner (2012), the time taken to reach maturity is tied to the organizational culture of the company and the nature of its business. Informal data gathered from the author's consulting firm show that companies reach full ergonomic maturity after 2 years of the beginning of the ergonomic consulting services.

The lack of ergonomic maturity in some companies may be associated with the fact that company management fails to accept and/or embrace ergonomics (Guizze, 2011). This is understandable if managers or other employees responsible for the ergonomic aspects in the company: 1) have been exposed to "poor ergonomics"; 2) think that ergonomics is a matter of common sense; 3) cannot visualize reasons for the company's investments in ergonomics and, therefore, are unable to demonstrate the benefits for the company; 4) have not been exposed to a sufficient number of evidence showing results of the cost-benefit of ergonomics by professionals working directly with this subject (Hendrik, 1996). However, it is possible to build a solid foundation to encourage and guide companies to achieve ergonomic maturity, provided the company is interested in it and the ergonomist employs appropriate methodology. We can consider as appropriate methodology the way the ergonomist will transfer his or her knowledge and the results of his or her work, dedicating a significant amount of time to a continuous monitoring of ergonomic issues and building change management of worker empowerment.

It seems clear that positive results do not depend solely on the ergonomic professionals, but also on macroergonomic aspects associated to the environment. When macroergonomics is not part of the ergonomist and company's view, the levels of ergonomic maturity are likely to be lower (Vidal et al., 2012). We can say that ergonomic maturity is a complex phenomenon that depends on several variables such as: technical qualification and years of experience of the ergonomist as well as the moment in which the demand for ergonomic analyses reached the company, be it for preventive or legal purposes. According to Guizze (2011), this complex phenomenon will lead to divergent opinions on the effectiveness of ergonomics in work environments. Some companies will adopt ergonomics as a strategy for opportunities to improve their production process and workstations whereas others – when ergonomics has not been able to solve their short-term or immediate problems – will only see it as a significant expense.

With that in mind, how does one know if the chosen strategy is driving the company towards ergonomic maturity?

Authors such as Vidal et al. (2012) and Guizze (2011) have contributed a great deal to the studies of ergonomic maturity. They have developed models based on information provided by the company's management, so they can better guide the ergonomist or the other professional in charge of the ergonomics in

the company. These models take into account the specification of the levels and dimensions of ergonomic maturity and emphasize the importance of implementing the relationship between maturity levels and their adherence to their practices (Guizze, 2011). In addition, Vidal and Santos' (2009) model mentions the nature of the initiatives, the degree of proactivity and the current ergonomic structure (committees) within the corporations.

Regardless of the model used to measure ergonomic maturity, success will be achieved once a network of relationships among the several different areas of the company has been established. When these relationships are managed in line with each company's particularities, an ergonomic culture will begin to emerge and, as a result, ergonomics will play a major role in the decision-making process of new projects and therefore have a positive impact on the entire production chain, benefiting both employers and employees.

ERGONOMIC CULTURE

Ergonomic solutions must be tailored to attend different scenarios in the company. These solutions will depend on the ergonomic awareness of those involved in the ergonomic projects (Kilbom and Petersson, 2003). We understand that this awareness is a consequence of an ergonomic culture. But how may ergonomic culture be conceptualized?

If we first think of the definition of the word "culture", we can say that it has a complex meaning and it includes everything that brings knowledge through art, beliefs, laws, morals, customs and all the habits and aptitudes acquired by the human being through family and social relations. ("O que é Cultura", n.d., May 2017).

The meaning of culture can be applied to ergonomics. In the literature, the concept of ergonomic culture is implicit in the definitions of ergonomics programs or of ergonomic maturity, making it difficult to find an isolated definition. The following provides the definition of ergonomic culture used in this thesis:

Ergonomic culture comes about when people are aware of ergonomic concepts, recognize the importance of ergonomics in their daily life and disseminate these concepts in the company in a way that these concepts are materialized through proactive ergonomic actions (for instance, think of and apply ergonomic concepts within the various projects of the production process). Therefore, ergonomic culture can be evidenced by the degree of proactivity among the various areas and professionals when it comes to ergonomics.

According to Khandan et. al (2015), it is imperative to promote and encourage the adoption of ergonomic behaviors among workers. This should be the case because ergonomic behaviors have no relation with demographic traits and can be improved through training, rules and regulations.

Ergonomic culture is the essential fuel for the success of ergonomics programs.

ERGONOMICS PROGRAMS

Ergonomics programs are mainly intended to allow for the implementation of ergonomic interventions in a progressive, continuous and organized way. An ergonomics program that is aligned with the company policies replaces individual ergonomic actions with a plan of ergonomic priorities involving several business areas of the company.

Larson (2014) indicates that companies that adopt ergonomics programs aim to reduce WRMSDs. Nevertheless, an efficient ergonomics program should go beyond that and provide countless solutions to the day-to-day challenges that often emerge when dealing with production processes. Problems may seem similar, but their solutions, as well as the contexts in which they appear, are unique for each company (Kilbom and Petersson, 2003).

Regarding the success of ergonomics programs, Hendrick (2002) suggests that there are five fundamental factors to be considered: 1. The participation of everyone in the company; 2. A macroergonomic perspective; 3. Possibility of continuous improvement; 4. A beginning with simple solutions; 5. Priority to user and company needs.

Also, to achieve success in ergonomics programs, it is necessary to manage them appropriately, complying with the policies and attending the needs of each company. The approaches of ergonomics programs that have proven to be successful could be of help. Larson (2014) introduced a successful worldwide program at 3M that covered elements like job assessment, adaptation of the work environment and worker training on the work floor. Moreover, it had both a macroergonomic (including management commitment) and a participatory ergonomic approach (including a stepwise approach in which the stakeholders' roles are clearly defined).

It is important to understand the difference between an ergonomics program and ergonomic practices, as the results of these approaches are different. According to Alexander and Orr (2006), many ergonomists apply ergonomic practices, where they learn to identify, analyze and solve ergonomic problems, but they do not design ergonomics programs and therefore cannot measure or manage ergonomic results within the company.

ERGONOMIC COMMITTEES

Ergonomic committee are critical elements of an ergonomics program (Silveira, 2004). Building an ergonomic committee in a company is a strategy used to manage ergonomic issues in the workplace by gathering professionals from various departments. An active ergonomic committee is the key to the success of ergonomics programs. However, setting up an ergonomic committee is not an easy task, since not everyone is aware of the importance of ergonomics and most employees already have an extensive schedule of other personal and professional commitments. Also, the large turnover of managers in the companies compromises the continuity of the work of the committee. Still, it is up to the ergonomic consultant – or the company's professional in charge of ergonomics – to motivate the continuity of the committee, regardless of the circumstances. Of course, this motivation must be linked to the support of the top management of the company to guarantee the smooth functioning of the committee's activities.

Depending on the author, ergonomic committee are given different names such as *Executive Ergonomic Committee* or *Executive Ergonomic Groups* (Couto, 2011). In this thesis, we use the term *"ergonomic committee."*

According to Fischer et al. (2002), the implementation of the ergonomic committee should take into account the type of organization and philosophy of the company.

Based on the variation in literature, it could be stated that the ergonomic committee should be customized for each company and the organization chart should be structured around a central or director committee and sub-committees, which contain a representative of each sector of the company, as shown in figure 1.

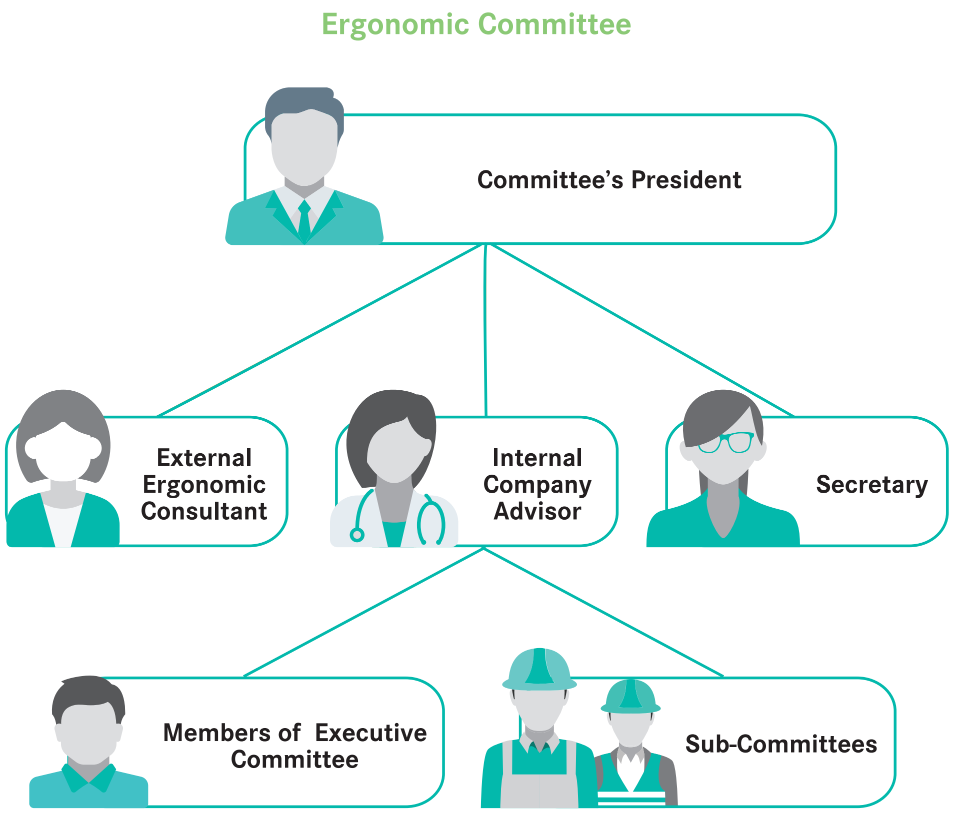


Figure 1. A possible structure of an ergonomic committee.

Generally, the participants of the sub-committees are of different hierarchical levels and appointed by their manager. They receive an invitation via e-mail and decide whether to participate in the committee or not. Once they have accepted the invitation, they become members of the ergonomic committee and undergo an initial 16-hour in-company ergonomic training given by the external consulting ergonomist. The main objective of this training is to provide committee members with basic ergonomic knowledge in ergonomics so that they can identify ergonomic issues and assist in the dissemination of an ergonomic culture throughout the company (Santos et al, 2006).

The executive committee may be composed by the company's management, production and innovation engineers, maintenance professionals, occupational safety technicians, physiotherapists, the external ergonomic consultant, and an internal company advisor. As a rule, work safety engineers or medical professionals are the ones appointed as internal advisors.

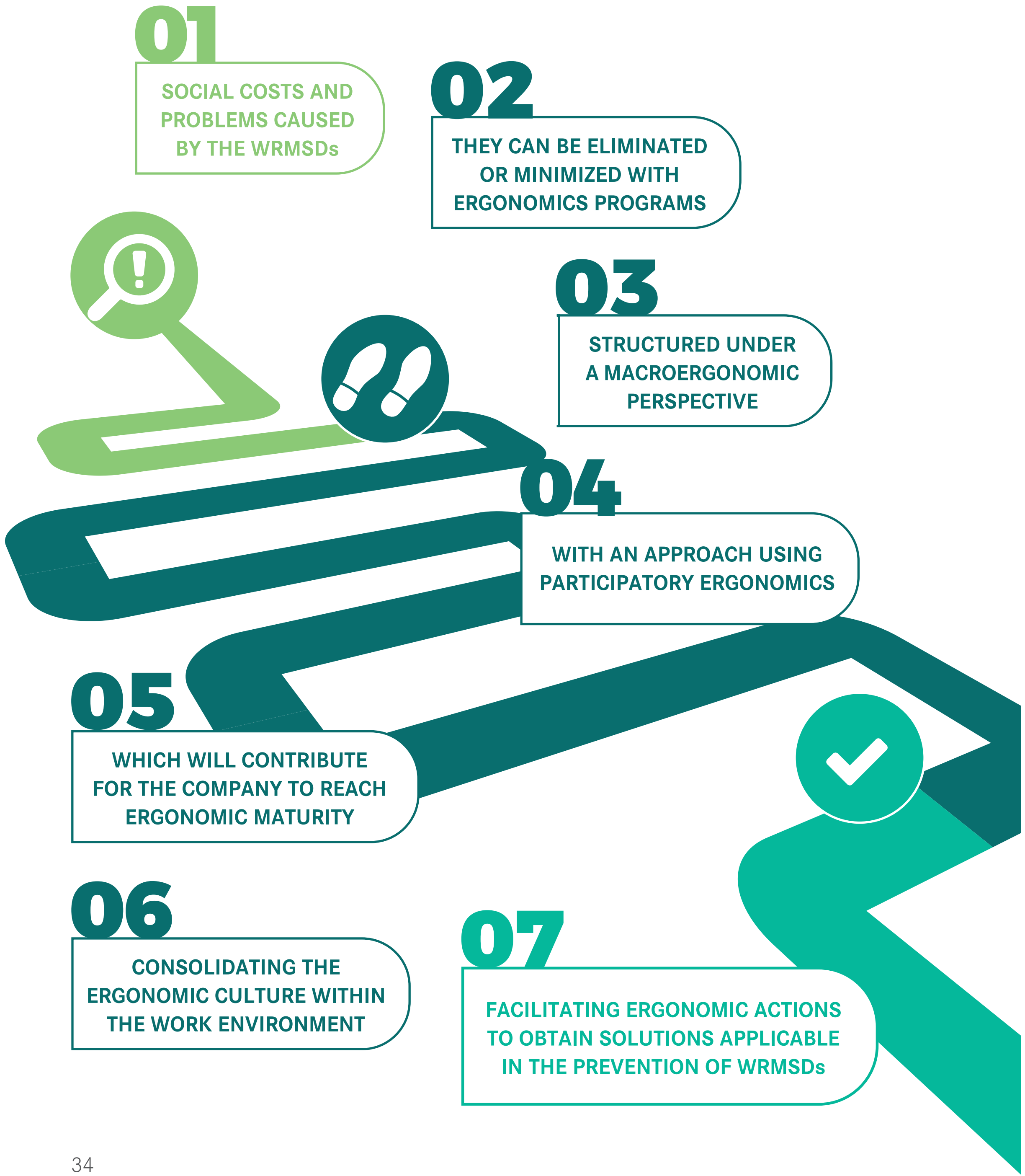
The schedule of an ergonomic committee includes: 1. meetings with the areas involved to discuss opportunities for ergonomic improvements; 2. ergonomic training for committee members and workers in general; and 3. other matters pertinent to the smooth functioning of ergonomic practices in the company, such as follow-up.

The number of people on the committees should be enough to represent each operational unit. According to Couto (2011), about 8 to 12 people from each operational unit, a coordinator and a secretary are enough. The possibility of inviting other employees to discuss specific issues at some committee meetings justifies having key people (managers and employees) as permanent members.

The formalization of the ergonomic committee requires approval and acknowledgement of the company's board of directors, as well as solid documentation that defines the committee's procedures. The author of this thesis has developed a procedure containing the objective of the committee; statute items; a chart with the desired profile for each member and the duties of the participating members (see Appendix I).

Vidal (2001) states that the ergonomic committee is the consolidation of the ergonomic function in the company and the organization's strategic response to the several different challenges faced by the Health, Safety and Environment (HSE) professionals concerning the relationship between worker health and productivity within corporations.

ORDER OF CONCEPTS OF THIS INTRODUCTION



PRACTICAL ISSUES IN APPLYING THESE THEORIES

The concepts described in this chapter seem promising and have been applied in several case studies in this thesis, which will be described in the next chapters. The overall research question is:

What challenges are faced in dealing with ergonomic risks in different industrial settings in a practical way?

As was stated in the beginning of this chapter, in all studies the same overall approach was applied, starting with checking the ergonomic maturity of the company. This seemed to work in these cases as it did lead to improvement. In the begonia case described in chapter 5, the company was rather immature and starting with tackling the WRMSD issues seemed to work. In chapter 4, the furniture company was more ergonomically mature, and the approach focusing on work movement worked. What should also be highlighted is the importance of the involvement of the employees and all other stakeholders from the start of the process. This phenomenon is already described by Hendrick (2002) and Vink et al. (2008).

Moreover, the objective of this thesis is to discuss and provide practical examples of ergonomic management in different industrial settings. It should be clear to the reader that this PhD thesis does not intend to provide guidelines or recipes regarding the actions to be taken after the identification of the level of ergonomic maturity of a company, since these actions involve the establishment of strategies that are dependent on the expertise and experience of each ergonomist as well as on the motivation of the company in regard to becoming more ergonomically mature.

This thesis consists of the following chapters, which highlight the challenges at different phases of interventions based on practice related to the theories:

Chapter 2: In most participatory approaches, the first phase of the project involves the gathering of data on the severity of the problem (Vink, Zink, Imada, 2008; Boeijen & Daalhuijzen, 2010). In gathering these data there are some methodological risks. Chapter two describes these risks as in practice data are used to look at the severity of the risk and shows that musculoskeletal problems have very different causes. For example, two workers performing different activities in the same room of an office, such as typing on the computer and cleaning the office, will present different ergonomic risks. Being in the same work environment, but performing different tasks, does not mean that the ergonomic risk is the same or homogeneous. Categorizing ergonomic risks in homogeneous exposure groups may underestimate or overestimate the ergonomic risk, bringing consequences for both employees and employers.

Chapter 3: After knowing the risks, an approach must be defined and choosing the involved parties as well as the members of the ergonomic committee can have an influence on the success of the intervention.

Chapter 4: In implementing the ergonomic intervention, it is important to take the individual differences of the workers into account. And this is not only the anthropometry, but also the way individuals work as these could be different as well. This issue is addressed in chapter 4.

Chapter 5: After performing the intervention it is important to embed it in the culture and system in the company. In this chapter links among the ergonomic approach, lean manufacturing and macroergonomics are discussed to demonstrate the success achieved in these ergonomic interventions. A reflection of the outcomes of chapter 2-5 will be given in chapter 6.

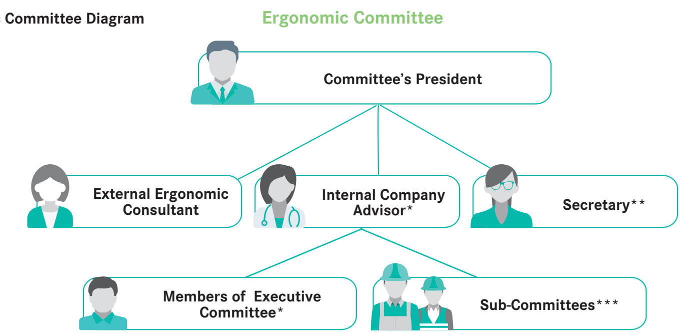
APPENDIX I (document created by the author of this thesis)

Code: ERGO 01 DATE: 05/15/2016 # of review:00	Type of Document: PROCEDURE Title: PROCEDURE FOR THE ERGONOMIC COMMITTEE	ergosys consultoria em ergonomia

Objective: Issue guidelines for the implementation and standardization of the ergonomic committee in the company

1.Purpose: Consolidation of the ergonomic function in the company and the organization's strategic response to the several different challenges faced by the Health, Safety and Environment (HSE) professionals concerning the relationship between worker health and productivity within corporations.

2.Ergonomic Committee Diagram



***Profile of the Internal Company Advisor and of the member of the Executive Committee:**
- Knowledge of operational area;
- Reasonable understanding of the process;
- Strong interest in the subject Ergonomics, Safety and Occupational Health;
- Capable of good articulation with workers' representatives;
- Capable of good articulation with management and other areas within the company.

****Profile of the secretary:**
- Good sense of organization;
- Maintenance of documentation registration in a reliable way;
- Monitoring the progress of ergonomic improvements, helping to manage the action plan;
- Scheduling of meetings and distribution of minutes.

Duties of the secretary:
- Responsible for the minutes, scheduling of meetings and other records of the ergonomic committee, establishing the annual calendar of the committee meetings and record the minutes.

*****Profile of the members of the Sub-committees:**
- Capable of actually solving problems or properly referring them;
- Are directly or indirectly involved with ergonomic issues in the company.

Duties of the members of the Sub-committees:
- Ensure that the company complies with the NR-17 of the Ministry of Labour and Employment;
- Identify work situations that can cause ergonomic problems;
- Participate in studies of new operational projects, as well as reformulations of ongoing ergonomic;
- Assist the Executive Committee in overseeing compliance with the ergonomic recommendations contained in the action plan.

3.Items to be considered in the Committe's Statute:
- The committee should have a book and record all the activities developed, the topics discussed, the actions taken, as well as the names of the participants. It should present the book when requested;
- The Executive Committee should be composed of the company director/committee chairperson, internal company advisor, external ergonomic consultant and at least 04 company professionals at management level;
- Each sub-committee must have a monthly meeting with the Executive Committee;
- The members of the committee can have their form of participation defined through "task forces" created in the establishment of the committee;
- All committee members should complete a basic, 16-hour ergonomic training at the company;
- Every two years, new members must be elected to the committee, with re-election of 50% of old members or 100% re-election possible if there are no new candidates for the committee;
- Prior to a 2-year period, any committee member wishing to leave it must send their request by e-mail to the committee secretary 30 days in advance.

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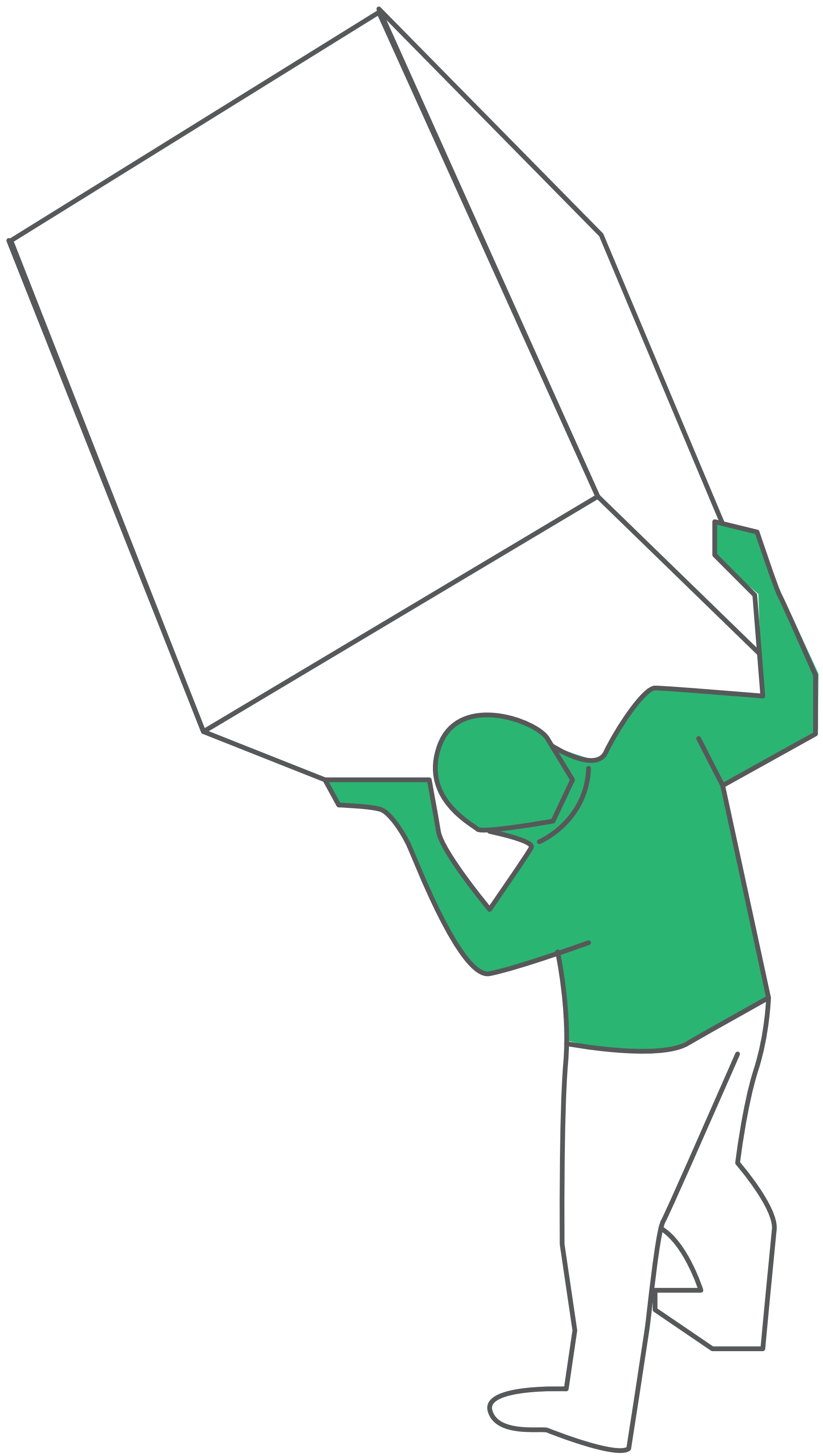

CHAPTER

2

Ergonomic Risks

Ergonomic Risk and Homogeneous Exposure Groups

Symone A. Miguez., Susan M. Hallbeck, Peter Vink,
Pedro Victor C. Rodrigues

In Proceedings of the Human Factors and Ergonomics
Society Annual Meeting (Vol. 58, No. 1, pp. 1551-1555). Sage CA: Los Angeles,
CA: SAGE Publications, September 2014

ABSTRACT

This study shows what employees in the Environment, Health and Safety (EHS) area within private Brazilian companies think about the relationship between ergonomic risks and Homogeneous Exposure Groups (HEG). Thirty-seven professionals from different market segments answered a questionnaire via Google Docs. The results show that 75.6% of the companies sampled use HEG in order to map occupational risks. Within those companies, 54% include ergonomic risks in their HEG, which has negative consequences to both employees and employers in these companies.

Keywords: Homogeneous Exposure Groups (HEG), Occupational Risks, Ergonomic Risk

Ergonomic Risk and Homogeneous Exposure Groups

INTRODUCTION

Within the Environment, Health and Safety (EHS) programs in several segments of companies it is necessary to perform a mapping to monitor the exposure levels of risk agents. Such measures provide the means to reduce or eliminate risks in order to safeguard the health of the workers and comply with current legislation. In order to manage those risks, the workers are included in a group called Homogenous Exposure Group (HEG).

The term Homogenous Exposure Group was first used in Brazil due to a Brazilian technical standard (Instrução Normativa nº 1, 20/12/1995) dealing with the evaluation of benzene levels in work environments. After this standard was enforced, the term HEG was adopted to refer to the exposure of workers to the remaining risk agents in the workplace (Lopes Neto, 2009). This term has been pervasive in Brazil and the use of HEG facilitates the identification of chemical, biological and physical risks; however, when it comes to physical risks referring to ergonomics, one must rethink the meaning of ergonomic risks.

In the literature, HEG refers to a group of workers who experience similar exposure in such a way that the results of the evaluation of the exposure of any worker of the group are representative of the exposure of all the other workers in that group (NR-22, 2011).

HEGs may also be defined as a group of workers engaged in similar tasks for the same period, in similar work shifts, in the same workplace and exposed to the same risk agent. (Hawkins et al, 1991).

There is general agreement for these definitions of HEG. However, when considering ergonomic risks and HEGs, it is essential to understand that the exposure factors of chemical and biological risks are different from those exposure factors of an ergonomic risk, which could be, for example, employing one's hand as a hammer. This task constitutes ergonomic risk for the upper limbs because it may include repetition, force exertion, awkward postures and repetitive impacts (Colombini, 2008). Now, imagine that this employee using his hand as a hammer is working in the same room as his supervisor, who has been given postural orientations and whose administrative tasks and workstation pose no ergonomic risk. Providing the first employee with a hammer and postural orientations will eliminate the ergonomic risk. This simple example allows us to say that the ergonomic risks will not always be the same just because the employees are in the same room. In other words, ergonomic risks will always be dynamic due to the fact that they can change. Nonetheless, if both employees are exposed to benzene in this room with the same exposure time, the chemical risk will always be the same.

Therefore, it is clear that the exposure factors are different. Once a chemical HEG has been established, one is aware of the source of the known risk as well as the exposure time within that work environment, assuming that the task itself does not interfere with the risk measurement process. On the other hand, as it has been mentioned, the exposure factors of ergonomic risks are related to different variables in the task. These variables will determine the frequency, duration and other complementary factors for the presence or absence of ergonomic risks.

Ergonomic risks constitute a vital aspect of study and prevention for the health of the worker (Kenny et al, 2012). The significance of this subject and its implications for both employees and employers are the motivation for the present study, whose purpose is to show that one must not include ergonomic risks in HEGs.

METHODS

Subjects

Thirty-seven professionals from four regions in Brazil (Northeast, Midwest, Southeast and South) participated in this study. All subjects were employees of the companies; they participated in the research voluntarily and the majority were Safety Engineers and Safety Technicians.

Survey

The data collection instrument was an online questionnaire via GoogleDocs, which was available for a period of two months. This questionnaire was sent to online discussion forums of professionals working within the Environment, Health and Safety (EHS) area in 37 different companies. The number of employees for the selected companies ranged from 50 to over 10,000.

The questionnaire contained 7 questions, 4 questions were closed-ended, 1 semi- open and 2 open-ended. The questions covered the use of HEGs and the inclusion of ergonomic risks in those HEGs.

RESULTS

Question 1. Are the workers divided into Homogeneous Exposure Groups (HEGs*) in your company?

*HEGs (or Similar Exposure Groups, SEGs) refer to a group of workers who experience similar exposure in such a way that the results of the evaluation of the exposure of any worker of the group are representative of the exposure of all the other workers in the group.

( ) Yes

( ) No

The results show that 28 companies (75.6%) use HEGs to identify groups of occupational risks whereas 9 companies (24.4%) stated that they do not utilize HEGs at all.

Question 2. Do you include information about ergonomic risks factors in your HEG?
( ) Yes
( ) No

More than half of the companies, which represents 20 enterprises (54%), include ergonomic risks in their HEG spreadsheets. The 17 remaining companies (46%) prefer not to add ergonomic risks to their HEGs.

Question 3. If you answered YES to the previous question, do you believe all the workers who occupy the same physical space in your company are classified into the same HEG even though they perform operational or administrative tasks?
( ) Yes
( ) No
Why?____

Although the majority of EHS professionals have reported that they include ergonomic risks in their HEGs, thirteen of them (65%) are aware that workers who share the physical space but perform dissimilar tasks should not be included in the same HEG. Only 7 professionals (35%) believe that employees holding distinct functions in the same work place have the same ergonomic risk and may, therefore, be added to their HEGs.

Question 4. The information about ergonomic risks factors in your HEG is obtained through:
( ) Ergonomic Analysis of Work (E.A.W.) carried out by an Ergonomist Certified by ABERGO*
(*To become certified, after specializing in ergonomics, the professional must take an exam at ABERGO – Brazilian Association of Ergonomics.)
( ) Ergonomic Analysis of Work (E.A.W.) carried out by a professional Specialist in ergonomics**
(**To be a specialist one needs to have taken a course specializing in ergonomics for at least 360 hours)
( ) Safety Engineer of the company
( ) Safety Technician of the company
( ) Other

Results show that information regarding ergonomic risks of HEGs is collected, by order of most frequency, by: safety engineers (7 - 35%); ergonomics specialists (5 - 25%); certified ergonomists (Certified Professional Ergonomist CPE (3 - 15%); safety technicians (3 - 15%); and other professionals (2 - 10%).

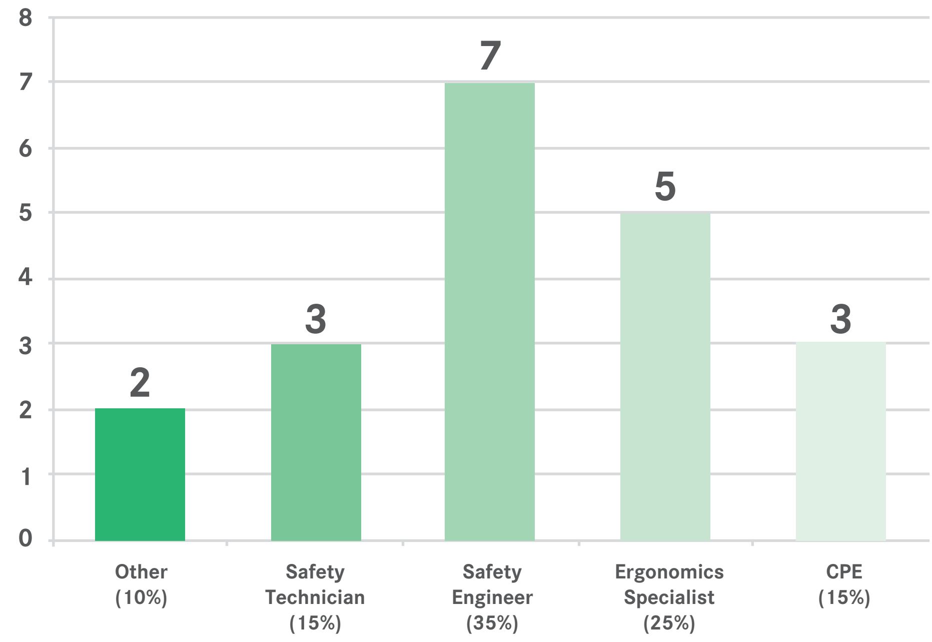

Figure 1. Percentage of professionals responsible for collecting information on ergonomic risks for HEGs.

Question 5. In your experience, the ergonomic risk factors included in the HEG can be considered:
( ) Dynamic risks
( ) Fixed risks

Results indicate that 21 respondents (56.7%) believe that the ergonomic risk is dynamic whereas 13 professionals (35.2%) think that the ergonomic risk is fixed just like biological and chemical ones. Three of the respondents (8.1%) did not provide an answer to this question.

Question 6. How many employees does your company have?

The graph below (figure 2) shows the percentage of the number of employees in each of the companies that participated in the survey. It must be highlighted that the largest number of participating companies possess from 50 to 100 employees (19%), followed by 18 companies that present an identical percentage of participation (16%) and whose number of employees range from 500 to 1,000; from 1,000 to 10,000 and over 10,000.

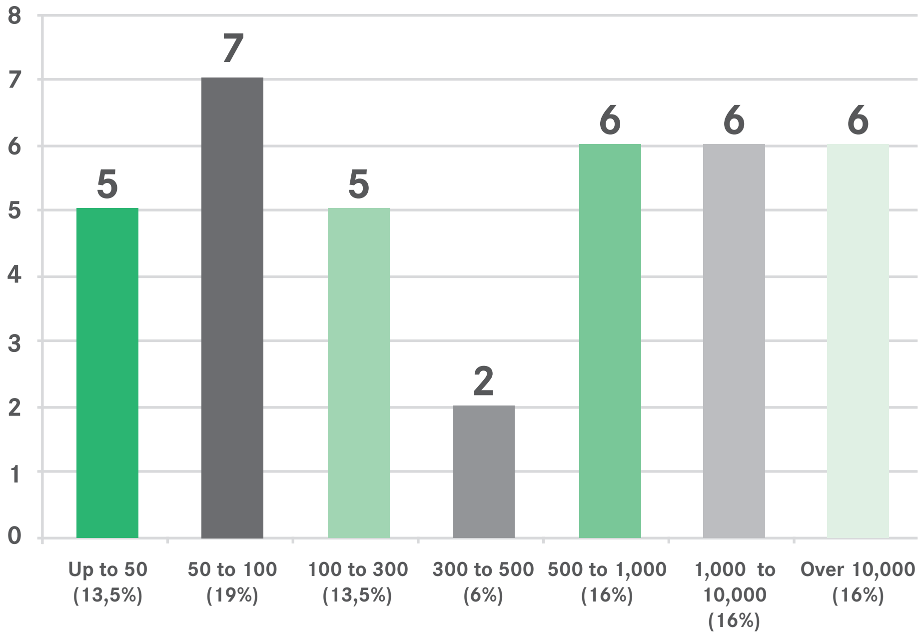

Figure 2. Participants according to company size.

Question 7. In which region is your company located?

The majority of the participating companies are located in opposite regions of Brazil. Nineteen of these companies (51%) are located in the Northeast whereas 16 of them (43%) are situated in the Southeast region of the country. The number of the remaining companies is presented in the graph below:

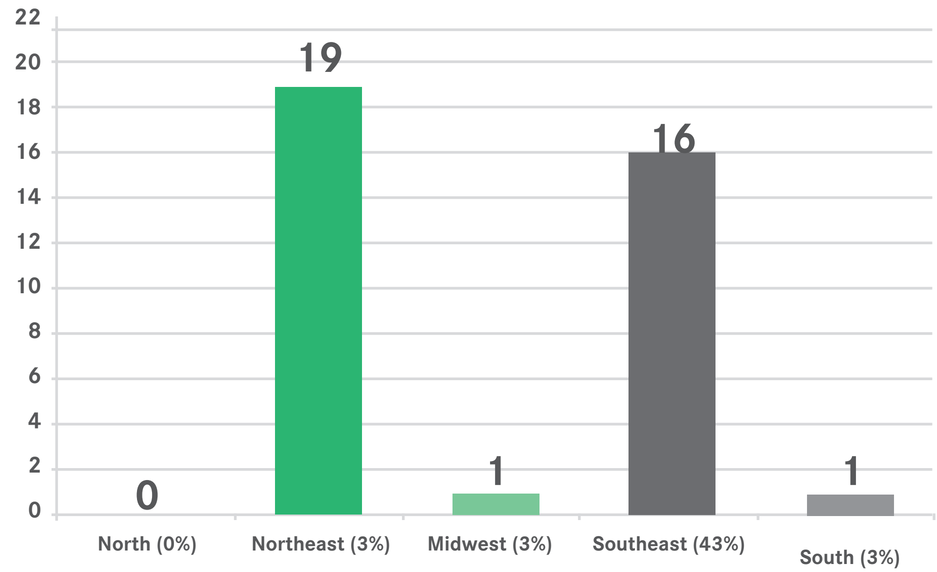

Figure 3. Percentage of the location of surveyed companies.

From the results presented so far, we will focus on both the Southeast and Northeast regions to have large enough regional samples to make generalizations.

These two regions present virtually the same percentage in regard to the use of HEGs to measure risks: 12 companies (75%) in the Southeast region and 14 companies (73.6%) in the Northeast employ HEGs in the mapping of occupational risks.

When asked about the inclusion of ergonomic risks in HEGs, 10 companies (62.5%) in the Southeast region and 9 companies (47.4%) in the Northeast region declare that they include ergonomic risks in their HEGs.

Four companies (40%) from the Southeast region think that when administrative and operational workers are in the same physical space, they should not be added to the same HEG. In other words, 6 Southeastern companies (60%) believe the opposite.

Eight professionals (89%) from companies in the Northeast region believe that workers in the same physical space should not be included in the same HEG when they have distinct tasks, namely, administrative and operational.

DISCUSSION

The most relevant results from the research on the inclusion of ergonomic risks in HEGs came from regions that are historically distinct in terms of economic and human development aspects in Brazil. On one hand, there is the Southeast region, which is highly industrialized, possesses the highest Gross Domestic Product (GDP) in the country (49.5% of the national total amount) as well as a high Human Development Index (HDI) of 0.754. On the other hand, there is the Northeast region that, despite having the third highest national GDP, possesses the lowest per capita GDP (U$4,435) as well as the lowest HDI (0.659). (IBGE, 2013; PNUD, 2013).

This demonstrates that matters addressed in this study have a remarkable representativeness of issues regarding ergonomic risks across a large difference in economic conditions.

The fact that occupational risks are widely mapped in these two regions (75% in the Southeast and 73.6% in the Northeast) clearly shows that this habit of using HEGs is highly valued by the professionals acting in those areas. We agree with this practice as long as non-ergonomic risks are involved.

Sixty-two point five per cent (62.5%) of the surveyed companies in the Southeast and 47.4% of those in the Northeast include ergonomic risks in their HEG spreadsheets; which does not reflect an appropriate practice. This view may be based on the fact that 60% of the professionals in the Southeast region state that when administrative and operational workers are in the same physical space, they should be added to the same HEG. If this concept is adopted in order to include the ergonomic risk in the HEG, it is inaccurate because the activities involved in the administrative and operational areas are completely distinct, even when workers share the same work place. Despite there being no agreement as to the inclusion of ergonomic risks in HEGs, this study has revealed that the professionals from the Northeast are better able to handle the concept of ergonomic risk. This is due to the fact that 89% of these professionals hold that workers performing different tasks in the same place should not be categorized in the same HEG.

This study has also shown that professionals from different areas are in charge of mapping ergonomic risks (figure 1). Thus, companies must be mindful of the professional qualification of the member of staff who collects and analyzes information on ergonomic risks.

It is the academic background of the professional who assesses ergonomic risks that will determine his or her view on the nature of ergonomic risks. In this research, from the 37 participating companies, the majority (56.7%) of them believe ergonomic risks to be dynamic, which indicates maturity in regard to the concept that, once an ergonomic improvement is established within the work environment, the ergonomic risk is eliminated or minimized.

It is believed, therefore, that the presented data follow opposite directions; in other words, although the EHS professionals in this study understand that the ergonomic risk is dynamic, they still include it in their HEGs. It is likely that this happens due to the large number of employees in the companies, which makes it laborious to perform an individual evaluation based on the employee's task or because they have been instructed to do so without asking further questions in regard to the issue.

CONCLUSION

This study shows that there is no consensus among the sampled professionals regarding the inclusion of ergonomic risks in the HEGs. Thus, this fact suggests the urgent need of more in-depth studies on the subject.

It is crucial to understand that ergonomic risks are dynamic, i.e., once an ergonomic improvement is performed in the workplace or guidance as to the best posture is offered, the ergonomic risk is eliminated or reduced, but with new equipment or processes, the risks must be reassessed.

The inclusion of ergonomic risks in HEGs leads to the underreporting of ergonomic risks within the company. This will have harmful impacts on both the health of the employee and on the management of the ergonomics programs of that company.

This research did not intend to exhaust the topic; instead, it sought to bring some results regarding the inclusion of ergonomic risks in HEGs in order to encourage EHS professionals to review their procedures in ergonomics. We believe that this will certainly improve the management of the ergonomics programs in which these professionals are involved.

ACKNOWLEDGMENTS

We thank all the professionals who answered our questionnaire, allowing us to bring about this reflection over such an important issue regarding ergonomic risks.

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CHAPTER

3

Ergonomic Management

A Successful Experience of Ergonomic Committee

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ABSTRACT

This article aims at sharing the strategies adopted during the establishment of an Executive Ergonomic Committee (ERGOCOM) within an energy company in Brazil. The methodology for forming the committee was based on different methods of the scientific literature, which allowed for the designing of a personalized approach that would cater for the specific ergonomics needs of the company. The approach was based on a 74-hour ergonomics training course given by the external consultant to 26 employees from several areas and hierarchical levels. Support from top management and the engagement of all committee members were pivotal for reaching positive results for both employees and employer.

Keywords: Ergonomic Committee, Quality of Life

A Successful Experience of Ergonomic Committee

Work-related Musculoskeletal Disorders (WRMD) are present in several countries (Hellig et al., 2017) and have been a recurrent research topic among professionals involved in ergonomics. They are responsible for designing solutions that either eliminate or reduce WRMD that affect workers of all industries when the work environment is not adequate for the tasks developed therein.

According to Larson and Wick (2012), companies seeking to solve WRMD will usually adopt ergonomics programs. They vary in the design and in the way they are created because they take into account the company's organizational structure as well as its operational and commercial goals. In addition, there are a few basic requirements for these ergonomics programs, so they must: 1. perform an ergonomic analysis of the workstations to assess ergonomic risk and plan control measures; 2. Manage results; 3. have the support of employees who possess technical knowledge on ergonomics; 4. instruct the workers in ergonomics and include them in the ergonomics programs (Hendrick, 2008; Larson & Wick, 2012). The last requirement may be met within the ergonomic committee.

These ergonomics programs bring about reflections upon the workers' process of awareness both in terms of beliefs as well as solutions for protecting and promoting health and improving the quality of life of all stakeholders (Oliveira & Fagundes, 2001).

Within a taxonomy of an ergonomics programs, the ergonomic committee are of great importance in the dissemination of an ergonomic culture in the company (Silveira, 2004). The ergonomic committee fits within the basic requirements of an ergonomics programs, within which the workers will have the opportunity to gain knowledge about ergonomics and share their technical knowledge. According to Antunes (2003), scientific knowledge and labour knowledge are more closely related in the contemporary productive world in the sense that the latter does not have to debunk the former.

Based on the view that ergonomic committee are part of a strong ergonomics programs, the goal of this article is to share strategies for the establishment of an Executive Ergonomic Committee (ERGOCOM) in a Brazilian energy company which valued both the interpersonal exchange among the several areas of the company and the contribution of the external consultancy.

METHODS

The establishment of the ERGOCOM was based on three different methods about committees found in the literature (Couto, 2002; Fischer et al., 2002; Silveira, 2004 and Vidal,2002). By applying this diversified knowledge, it was possible to set up an ERGOCOM with a personalized strategy based on the specific needs of the company. The ERGOCOM was structured following 11 steps. Some of them happened simultaneously. However, in order to make it easier to understand each step, they are described in their chronological order below:

Step 1 – Demand for the establishment of an ERGOCOM

Two demands gave origin to the ERGOCOM: 1. A demand from the company that had an ongoing, six-year-old ergonomics programs with several actions, but wanted to increase the knowledge of Ergonomics of its employees and centralize the ergonomic actions with the help of the committee; 2. The need to comply with the union's collective agreement requiring the company to maintain ergonomic committee in its organizational structure.

The ERGOCOM was established with the approval of the company's top management. According to Couto (2002), the support from the top management is the first pillar for the effectiveness of an ERGOCOM.

Step 2 – Hiring External Consulting

Any outsourced consulting firm and everything that involves Ergonomics must follow a methodical, set and contextualized itinerary (Vidal, 2002). Faced with this challenge, the company decided to hire an external consultancy with a certified ergonomics professional for six consecutive months to enable the implementation of the ERGOCOM and the duly qualification of its members.

Step 3 - Awareness Lecture

The process aiming at raising the awareness of the workers began with a printed invitation, signed by the top management of the company. To participate in the lecture, entitled How Ergonomics can help you in your day to day, the invited professionals should confirm presence until the date set by the organizers of the event. The Ergonomics consultant gave several one-hour lectures, thus providing the opportunity for all employees to receive information on Ergonomics and the ERGOCOM project.

Step 4 - Selection of ERGOCOM members

According to Couto (2002), the number of members of an ERGOCOM varies from company to company, but the number of participants should not be too high to avoid operational troubles.

The initial challenge was to select members for the ERGOCOM as there was a request from top management to include all areas of the company, incorporating both effective employees and service providers.

The number of effective employees was 197, 26 in the administrative area and 171 in the operational area. The direct service providers comprised 128 workers, 93 of whom were from the administrative area and 35 from the operational area.

Faced with the large number of employees and the diversity of the company's work sectors, the managers of each sector were asked to appoint an employee to be a member of the ergonomic committee. Another way of joining the committee was the so-called self-nomination, that is, at the end of the awareness lecture, the professionals who wanted to be part of the ERGOCOM could request the inclusion of their names and, if approved by their managers, they would join the ERGOCOM.

After being selected, ERGOCOM members were invited to attend a meeting with the external consultant, physiotherapist and manager of the company to clarify the responsibilities of the members, emphasizing that membership was voluntary. A total of 26 employees of different sectors and hierarchical levels of the company joined the ERGOCOM.

Step 5 - ERGOCOM Organization Chart

The ERGOCOM structure was subdivided into Central Committee and Sub-committees (figure 1).

The Central Committee is composed of a general coordinator of the committee (manager of the company), a sub-committee coordinator (Physiotherapist and ergonomics specialist of the company), an internal advisor (company doctor), an external ergonomic consultant, 1st and 2nd secretaries (effective employees of the company) and members of the central committee (effective employees of the administrative area).

Effective employees and service providers of the operational areas may be members of the sub-committee. Six sub-committees were formed to cover all operational areas of the company.

Other participants of the ERGOCOM formed a multidisciplinary team including an occupational physician, a physiotherapist specialized in ergonomics, engineers and safety technicians, electrical and mechanical engineers and technicians, operators and professionals in the areas of management, computer science, environment, training, human resources, supplies and members of the Internal commission for the prevention of accidents.

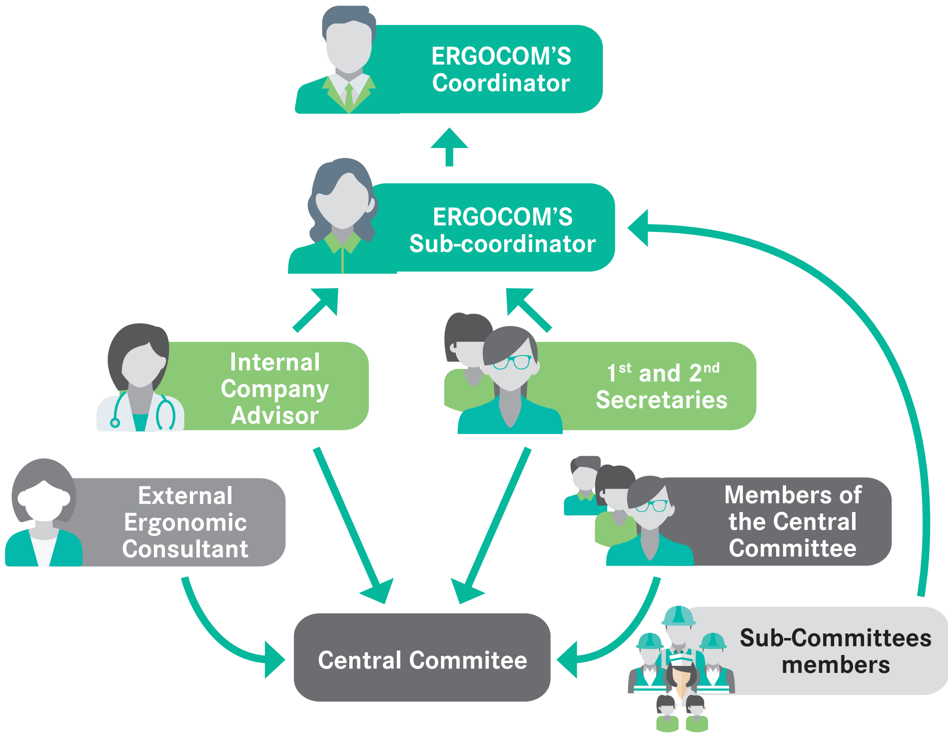

Figure 1. ERGOCOM organization chart within an energy company.

Step 6 - Training ERGOCOM Members

There is nothing more detrimental to thinking than providing the right answers (Alves, 2003). During the preparation of the content for the 74-hour training program for 26 members of the ERGOCOM, there was no intention to exhaust the subject on Ergonomics or even to simply give the solutions to all ergonomic problems.

According to Kilbom and Peterson (2006), ergonomic training should be adapted to the real situation of the workers. Therefore, monthly theoretical-practical classes were given considering the real conditions of the work environment of the participants. At the end of the trainings the members of the committee could carry out a pre-diagnosis of the work situations in the company, helping the sub-coordinator of ERGOCOM to draw up action plans that could drive positive changes within the assessed work environment.

Step 7 - Internal Instruction

The formalization of the committee through a minute provides legitimacy to it, allowing its members to feel free to carry out their duties (COUTO, 2002).

The establishment of an internal instruction was needed in order to formalize the creation of the committee and design guidelines such as: ERGOCOM's roles and responsibilities, the duration of the committee's term in office (established in 2 years), the frequency of the meeting (established in once a month), and other criteria contributing to the logistics and smooth running of the committee.

Step 8 - Elaboration of indicators

It is usually difficult to measure the results of ergonomics programs because they involve changes in aspects such as work relations, organizational culture, safety, atmosphere and comfort in the workplace (Silveira, 2004). Measuring the results of an ergonomic committee is another very demanding task. However, in order to monitor the results of the ERGOCOM, the members of the central committee and the ergonomic consultant developed four indicators: 1. Operations, 2. Performance, 3. Effectiveness, and 4. Impact. In relation to the operations indicator, the goal was to compare the budget allocated for ergonomic interventions versus the amount used after the ergonomic committee had been established.

In regard to the performance indicator, it aimed to compare the cost of the man-hour versus the workers leave of absence due to musculoskeletal problems.

With reference to the effectiveness indicator, we sought to identify the relationship of number of accesses in the Ergonomics link on the interaction channel ERGOCOM-Workers versus the number of ergonomic improvement requests made by the workers themselves.

The impact indicator was designed to check the participation of ERGOCOM members. This indicator was intended to quantify the participation rate of committee members versus the number of ergonomic improvements in which they were involved and helped to implement.

The senior management of the company and the central committee participants reviewed these indicators monthly.

Step 9 - Creating a Logo

The creation of a graphic symbol to represent ERGOCOM was necessary to establish a visual contact in the identification of actions of ERGOCOM for the other workers. One of the committee members from the communication area created the logo. After the presentation of several logos to the members of the committee and to the external consultant, the logo was chosen and started to be used in all matters involving the ergonomic committee.

Step 10 - ERGOCOM Media

The set of all knowledge acquired in a given field is called culture (Ferreira, 2004).

The members of ERGOCOM understood that other workers should have access to ergonomic knowledge on a frequent basis so the development of an ergonomic culture could take place in the company. The chosen medium was the creation of a biannual journal entitled ERGOCOM - Ergonomic News, which provided ergonomic tips for personal and professional routine activities.

Step 11 - ERGOCOM-workers Interaction Channel

Using the company's internal communication tool, the IT department and the internal physiotherapist specialized in ergonomics created an Ergonomics link made available to all employees. This tool makes it possible to obtain various information on Ergonomics, Ergonomics regulation from the Ministry of Labour (NR17), tips on adopting the correct postures in the work environment and in daily activities. The tool also allows the employee to make requests regarding the ergonomic assessment of his or her workstation. The ergonomic request item is directly linked to the ERGOCOM's sub-coordinator, who receives the online requests, looks for the employee who made the request, performs the ergonomic analysis and then, with the support of the management of the sector, issues a report containing suggestions for improvements, cost-benefit information and establishment of deadlines for the implementation of the improvement. This way, the visits to the link are registered and controlled by a computerized process, facilitating the control of data in a statistical way and promoting effective monitoring of the improvement processes.

RESULTS

After the first six months of the establishment of the ERGOCOM, the results, though still partial, were rather positive:

- 59% of the ergonomic nonconformities were all solved and 41% are now included in the company's action plan.
- There was a 72% reduction in absenteeism due to work-related musculoskeletal disorders.

DISCUSSION

Ergonomic issues may even be similar, but the context in which they are inserted is always unique. Therefore, experiences acquired in one setting may not be automatically applied to another setting (Kilbom and Petersson 2006). One must always take into account the company's culture, how much it is willing to invest in Ergonomics and the degree of commitment of its board and workers in regard to ergonomic matters.

In this study, we have described the steps for creating an ergonomic committee under a unique perspective aimed at an energy company and whose differentials stand out in each step of the implementation of the committee. We can say that several actions were innovative, such as: Meeting the demands of a union agreement (Step 1); Hiring an external ergonomist certified by the Brazilian Association of Ergonomics to work alongside the company's internal ergonomic specialist (Step 2); Lectures to inform and invite workers to participate in the committee (Step 3); Hire service providers who perform daily work in the company as members of the ergonomic subcommittee (Step 4); Creating a logo to identify committee actions (Step 9); Channels of communication and disclosure of the committee activities (Steps 10 and 11). It should also be noted that, in all the steps, the combination of the experience of the ergonomic consultancy with the expertise of the company's ergonomic professional was a great differential and something unusual in Brazilian companies. We believe that these aspects contributed to the results shown here.

CONCLUSION

The limitation in this study was the fact that it was not possible to follow and present the indicators of the twelve months after the creation of the ERGOCOM. This happened because the consulting contract lasted only six months. However, we can see several ergonomic improvements being made, the involvement of 100% of the committee, the motivation of the entire company in this project, constant support from top management and the results related to the decrease in absenteeism due to musculoskeletal disorders. This positive scenario has certainly pointed to the success of this ERGOCOM, and it has also highlighted the fact that the continuation of an ergonomic committee is as important and challenging as its beginning.

Ergonomic committees should not be confused with an ergonomics programs, but rather as being part of the program, where participants can help find and implement ergonomic improvements in the work environment with the involvement of ergonomic professionals.

This study does not intend to dictate standards for the implementation of ergonomic committee, on the contrary, it simply aims to share an experience that was noticeably successful.

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Ergonomics Program Management in Tucuruí Hydropower Plant Using TPM Methodology

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ABSTRACT

This paper presents the benefits achieved in the management of ergonomic processes in Tucuruí Hydropower Plant with the use of the TPM methodology (Total Productive Maintenance). This methodology is aligned with the corporate guidelines and with the Strategic Plan of the company, also, it is represented in the TPM Pillars, including the Health Pillar, in which the ergonomics process is inserted. The results of the ergonomic actions demonstrated a 12% reduction over the absenteeism rate due to musculoskeletal disorders, solving 77% of ergonomic non-conformities. This favored the rise of the Organizational Climate in 44,8% and positively impacted the overall performance of the company. The success of this work has been confirmed by the achievement of the following awards: Award for TPM Excellence in 2001, Award for Excellence in Consistent TPM Commitment in 2009 and, more recently, the Special Award for TPM Achievement in 2010. The determination of the high rank administration and workers, along with the involvement and dynamism of Pillars, have assured the success of this management practice in Tucuruí Hydropower Plant.

Keywords: TPM, Hydropower Plant, Health Pillar

Ergonomics Program Management in Tucuruí Hydropower Plant Using TPM Methodology

INTRODUCTION

Property of Eletrobras Eletronorte, Tucuruí Hydropower Plant, located about 400km away from Belém, in the city of Tucuruí in the state of Pará, is the largest hydropower plant when it comes to 100% Brazilian generation (8,370 MW), as the Itaipu plant is binational. The plant went into commercial operation in 1984 and has become one of the greatest engineering works in the world. The Tucuruí Plant acts in the electricity business, under the status of utility company. Its core competency is the availability of electricity generation capacity to the National Interconnected System, through the operation and maintenance of Hydraulic Generating Units. Tucuruí plant has a workforce of approximately 500 people. The strategic guidelines of organizations conduct their actions to achieve market growth through the development of specific software, implementation of international standards, processes automation and use of robots. Nevertheless, the facilities and equipment are not sufficient to ensure the success of those organizations. In this perspective, the journey of Tucuruí plant for Business Excellence started with the implementation of the program of quality and productivity in 1993. Eletrobras Eletronorte is always in a continuous search for improved management of its processes; in 1999 it began the implementation of the TPM methodology (Total Productive Maintenance), with consultation of JIPM (Japan Institute of Plant Maintenance), resulting in the achievement of the Award for TPM Excellence - Category A, in 2001.

TPM was developed in the 70’s in Japan and is a tool to improve the quality of products and services [1]. It is instituted on redesigning and improving the business structure from the restructuring and progress in the performance of people and equipment, involving all hierarchical levels and changing the organizational posture. The TPM is a management tool that provides increased productivity by reducing losses. The implementation of TPM in the company was crucial in attaining new proofs of acknowledgement of it, such as: Prêmio Qualidade da Gestão Pública (Public Management Quality Award) in 2002; Prêmio Qualidade do Trabalho (Labour Quality Award) in the period from 2000 to 2008; certification of financial processes and achievement of NBR ISO 9001, conjointly with NBR ISO 14001, regarding the Environment, in the period from 2007 to 2009. And also, the company has earned the recognition of the Fundação Nacional da Qualidade (National Quality Foundation) under the criterion of Leadership, People and Society in the years 2009 and 2010, and the SMMT / JIPM, which granted the plant the Award for Consistent TPM Commitment in 2009. It should be noted that, in 2010, Tucuruí was rendered the head office of the Eletrobras Eletronorte generation process and became responsible for the managing of a Superintendence. It consists of three generating plants and establishes itself as the mother plant for TPM methodology promotion in the company; it also expands this role when leading the dissemination of the methodology to various stakeholders in its production chain and makes use of the TPM methodology as a fundamental practice for the achievement of Business Sustainability. In the same year, Tucuruí delved into the quest for the Special Award of JIPM, being the only power company in the world to achieve this level of recognition. These awards were only made possible because the implementation of the TPM methodology is aligned with the Strategic Plan of Eletrobras Eletronorte. The writings point that TPM is composed by 8 basic pillars that must be followed during implementation for the results to be achieved [2], however, in Tucuruí, the methodology was proactively structured onto 11 pillars, they are: Business Sustainability, Focused Improvement, Autonomous Maintenance, Planned Maintenance, Early Management, Quality Maintenance, Office, Training and Development, Safety, Health and Environment. Each pillar has a specific objective and contributes to achieving the general objective of the TPM in Tucuruí, defined as: Increase the availability index (ID) and reduce the operational cost of energy. As an object of this study, we present how the Health Pillar contributes to the achievement of the TPM objective in promoting the overall health for all employees, thus providing a healthy and safe work environment through the ergonomics program. It is noteworthy that the Health Pillar coordinates the treatment of ergonomic hazards through the ergonomics program and deploys new improvements aimed at eliminating the risks and / or minimizing them by using the company's learning system, the infinite looping. Furthermore, it is noteworthy that the focus of the Health Pillar is the human factor, strongly based both on the evolution of technical training and on the optimization of the work carried out by humans. Re-education and pro-activity for the prevention actions are great allies to the success of organizations during the 21st century.

TOTAL PRODUCTIVE MAINTENANCE METHODOLOGY

The TPM is a methodology that emerged in Japan in the 70's in a company related to the Toyota group, and quickly became part of the organizational culture of this great company and also of its suppliers and affiliates. Later, other companies adopted it in industry segments of serialized processes [3]. To Nakajima [2], "TPM can improve the overall effectiveness of the facilities through an organization based on respect for human creativity and the general participation of all employees of the company." According to Suzuki [4], there was a rapid growth of TPM in assembly industries, particularly companies in the automotive and household appliances areas, as well as among manufacturers of semiconductors and electronic components. It was also introduced in continuous process industries (petroleum refining, chemical, steel, food, gas, ceramic, cement, paper, pharmaceutical, metallurgical, glass, tyres and publishing). Again, to the same author "there are three strong reasons for the TPM popularity in Japan: the expressive range of outstanding results in operations; improving the factory environment and the possibility of obtaining PM Distinguished Plant Prize (PM Prize)".

According to Ribeiro, "In Brazil, many companies have adopted TPM, based on some principles of teamwork and autonomy as well as a continuous improvement approach to prevent breakdowns." [5] Ribeiro also notes that "some companies operating in Brazil have consolidated the deployment process, including some recognized by the award of JIPM. They are: Yamaha, GM, Alcoa, Pirelli Cabos, Pirelli Pneus, Andréas Stihl, Alumar, Texaco do Brazil, FIAT, Copene, Ford, Azaleia, Marcopolo, Multibras, Editora Abril, Votorantin Celulose e Papel, Eletronorte, Gessy Lever, Tilibra, Cervejaria Kaiser, Ambev, etc.". According to Mirshawka and Olmedo [6], "TPM is a maintenance program which involves the set of all employees of the organization, from senior management to the workers of the production line." Each author uses different words and expressions to define this program, but the important thing is that it is a management program that has been widely deployed in several companies around the world. TPM has clear objectives, which must be followed in order for the goals to be achieved. Those objectives are: Zero Break, Zero Defect, Zero Accident, Zero Loss, Zero Pollution and Total Quality. As to reach those objects, TPM uses implementation steps. Campos et al. apud Carvalho, Pereira & Turrioni [7], list four steps for the TPM implementation, unfolded into a total of 12 steps. The pillars of TPM methodology are discussed in detail below.

TPM PILLARS IN TUCURUÍ HYDROPOWER PLANT

For TPM to be possible there is a methodology based on eight principles, known as the eight pillars of TPM. As mentioned earlier, Tucuruí plant set along with JIPM the formatting of the eleven pillars as shown in Figure 1.

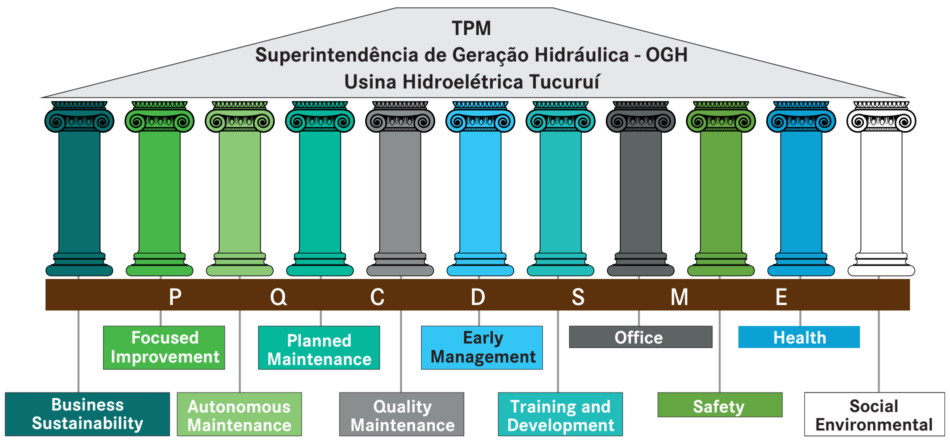

Figure 1. Eletrobras Eletronorte's TPM Pillars.

Each pillar of TPM is correlated with the Strategic Plan, Policies and Objectives of Eletronorte, based on the BSC (Balanced Scorecard), as shown in Figure 2. It should be noted that ergonomics is more specifically addressed in the Health pillar under the perspective of People and Learning with the corporate objective of "Increasing the productivity of the workforce" and under the Early Management pillar with the corporate objective of "Making business processes more efficient," and it could be inserted into the other nine pillars.

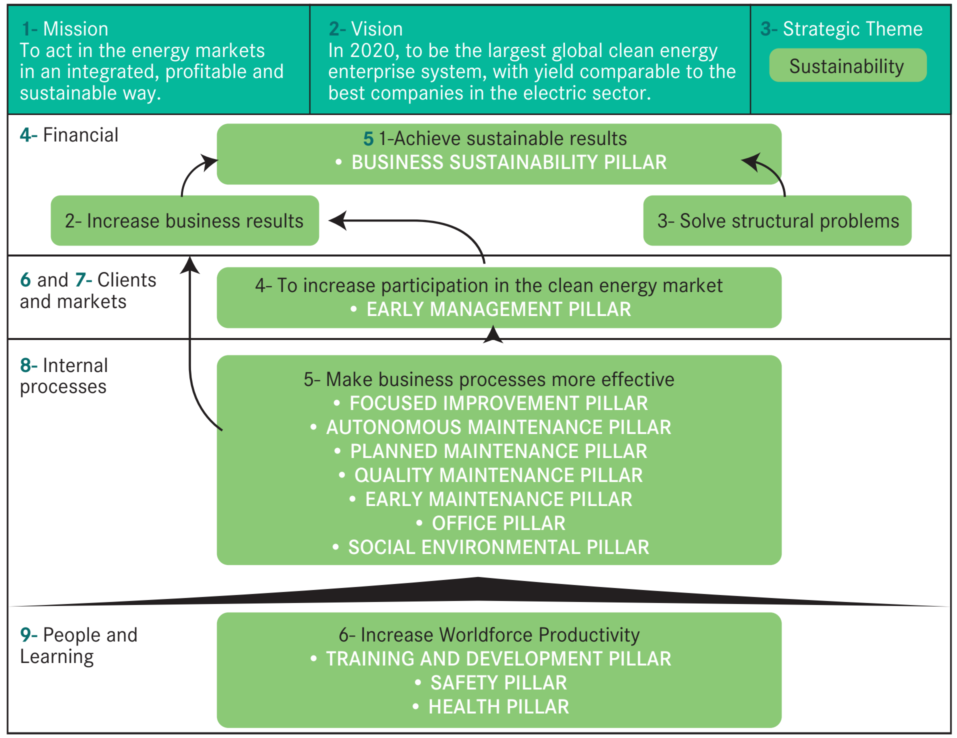

Figure 2. Strategic Plan and correlating pillars of TPM.

DEFINITION OF PILLARS

Business Sustainability Pillar

Its premise is to share responsibilities with a focus on the concept of social growth, on income generation and especially on encouraging the vocation of each municipality, thereby providing involvement and empowering people for effective sustainable growth with respect to the environment and future generations.

Focused Improvement Pillar

The activities of Focused Improvement fundamentally intend to identify and eliminate all losses and, consequently, obtain growth of the effectiveness of equipment, systems and productive processes, through the utilization of techniques of analysis and improvement (Kaizen), promoting substantial alterations that will ultimately lead to achieving maximum productivity limits.

Autonomous Maintenance Pillar

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus letting the qualified maintenance personnel to focus on higher added-value activities and technical repairs. Operators are responsible for maintaining their equipment to prevent deterioration.

Planned Maintenance Pillar

It is the grouping of all maintenance activities carried out by maintainers, i.e., by employees of the maintenance team. All these mentioned activities aim at:

- improving equipment availability;
- improving the maintenance efficiency;
- reaching an optimal level of loss reduction;
- achieving zero accidents;
- developing maintenance techniques that enable a reduction in intervention time and involved costs;
- improving maintenance structure and management;
- supporting activities of operation teams.

Quality Maintenance Pillar

This pillar is dedicated to the clients' delight through highest quality result of defect free manufacturing. The focus is on eliminating non-conformities in a systematic way as well as on Focused Improvement. Quality Maintenance activities establish equipment conditions that may result in any quality defect, based on the basic concept of perfect equipment maintenance to maintain the perfect product quality. The conditions are verified and measured in the historical series and those values that are held within standard range will be the ones to avoid defects. The transitions of measured values are watched in order to foresee the occurrence of defects and subsequently take defensive measures beforehand.

The Quality Maintenance Pillar in Tucuruí plant has the main objective of monitoring the quality of product, electrical energy, by monitoring indices referring to its quality.

Early Management Pillar

This pillar seeks alternatives to develop new products and invest in the acquisition of more efficient equipment in order to take preventive action, thus anticipating situations of breakdowns and losses. The goal in TPM is to drastically reduce the time from development to full production and get the "vertical start-up" (a quick start of operation, defect-free - on the first attempt).

Training and Development Pillar

This pillar seeks to structure the actions of education and training in a way to enable the increase of knowledge, skills development and behavioural changes, in constant search for a team that possesses mastery over its equipment and exhibits proactive attitudes.

Office Pillar

The identification and conceptual dissemination of the processes of the Office aims to empower employees to visualize these processes in an integrated manner and, from this focused integrated view on processes, solidified through a methodology conceived upon the philosophical principles of TPM, they will establish standards, procedures and indices to allow for evaluation, analysis and continuous improvement of these processes. So, all this is to ensure continued support from the office to activities of operating, maintaining, marketing and expansion of the company.

Safety, Health and Environment Pillars

The Safety, Health and Environment Pillars comprise a set of actions linked to policies and programs instituted in the company, being a part based on legal aspects related to Occupational Safety, Health and Environment. Moreover, they also focus on assistance policies and programs linked to the health of employees in seeking to maintain the level of zero accidents, physical and mental health of employees, and environmental management with improved quality of life [8].

The ergonomics program originated in 2001 with the implementation of the TPM in 1999 and it aims to contribute to the achievement of the objectives of the Health Pillar. The program is supported by the Ergonomic Committee - COERGO - covering several actions, a few of them are: Ergonomic Analysis of Work through weekly inspections, Workplace Calisthenics, Postural School, Relaxation Time; Functional Therapeutic Academy. The objectives of the ergonomics program in Tucuruí are:

- Adapt the environment and all its constituents and jobs to our workers;
- Enhance the well-being and overall system performance;
- Be compliant with the Brazilian Legislation (NR17 of the Ministry of Labour and Employment);
- Prevent work related disorders;
- Render the ergonomic moment the access to the integration of different sectors: Supplies, Occupational Safety and Health, Human relations and foremost the Production sector;
- Humanize the work processes;

- Make the working environment the integration source;
- Add value to the end-product by humanizing our production.

Before conducting the TPM process in Tucuruí plan, a TPM secretariat was initially established with full dedication to the dissemination of the techniques of the program, which reports directly to the Superintendent of the plant and acts as an internal consultant assisting various departments in the implementation of the TPM.

METHODOLOGICAL ASPECTS

Among the eleven pillars that guide the management of TPM in Tucuruí, this article focuses on the application of the Health Pillar, which emphasizes the use of techniques aiming to improve the efficiency of health management. For the development of the work, methods such as gathering of technical literature and references, direct observation, unstructured interviews and quali-quantitative methods were employed.

For this study, it was necessary to use data collected directly from the pillar management for the development of TPM methodology.

Regarding the type of research, Vergara [9] classifies it as to ends and means. As for ends, using descriptive and explanatory research, explanatory one clarifies some factors occurring in the company, plus, it assumes the descriptive research as the basis for its explanations. On the other hand, the descriptive one is used due to part of the literature research about the matter and for the description of TPM methodology in the surveyed company.

The research strategy adopted in this work is the case study. According to Godoy [10], the case study has become the preferred strategy when researchers seek to answer the questions “how” and “why” certain phenomena occur. As for the means, this study is considered a case study because it describes the management of the Health Pillar using the TPM methodology in loco, through the theoretical presentation of this methodology and the results obtained in a real case.

CASE STUDY: THE HEALTH PILLAR

The Health Pillar has the general objective of promoting the quality of life with integral health for all employees and their families.

Fernandes [11] conceptualizes Quality of Working Life - QWL - as a dynamic and contingent management of physical, technological and sociopsychological factors that affect the culture and renew the organizational climate, reflecting in the well-being of the worker and in the productivity of the company.

This pillar is also responsible for occupational health management in Tucuruí, it was structured in 1999 with the implementation of TPM in the company. Initially, the Health pillar was conducted in conjunction with the Safety pillar, afterwards it was dismembered in 2003. From that period until the present day the pillar has undergone several improvements in its management process. It currently has an organizational structure consisting of coordinator and surrogate members and others with various areas of expertise of health care such as a doctor, physiotherapist, nurse, social assistance worker, physical education teachers, administrative assistant and nutritionist, with further support from members of the HR (human resources) and IT (information technology). The pillar is connected to the TPM promotion secretariat of Tucuruí Hydropower Plant.

According to Campos [7], one of the most important concepts of quality programs is the premise that the only thing that improves is the thing that can be measured, and therefore, one must first measure and then improve. Thus, it is necessary to systematically assess the satisfaction of the company professionals, as in a self-awareness process, in which internal opinion polls are an important tool to detect employees’ perceptions about the factors affecting the quality of life and work organization.

To structure the Health pillar initially, a historical survey was held in order to identify critical points related to the health of employees. To address the identified problems, specific objectives, indicators and goals to be achieved were defined.

The actions developed in the Health pillar are deployed in the Master Plan with a schedule for 04 years and are divided by areas of expertise in the company.

LOSS TREE

It aims at conducting a study on losses related to health costs in Tucuruí, along with the Focused Improvement pillar, whose main objective is to eliminate losses related to benefits management where health-care costs have a direct impact.

The study of the Loss Tree and Costs Tree provides a detailed analysis of health care costs in Tucuruí, then, as to implement improvements in the ergonomics programs to reduce costs of absenteeism related to musculoskeletal disorders and costs with ergonomically correct adaptations/adjustments of the plant.

OCCUPATIONAL HEALTH

Manages the Occupational Health and Medical Control Program (PCMSO), with actions aimed at prevention and control of employees' health through periodic medical examination, immunization and awareness campaigns, nutritional assessments, check-ups with specialists (breast cancer specialist and urologist) and control of five health risk factors (BMI - body mass index, blood pressure, triglycerides, glucose and cholesterol).

ERGONOMICS

Companies develop strategies to manage their business and it could not be different when we think of ergonomic actions programs.

We consider that the ergonomic actions programs in companies are "key" to harvest the benefits of ergonomic education amongst people [12].

The reflections generated by these programs bring to the surface workers' awareness imbuing processes related to their beliefs and solutions over the problem of protecting, promoting health and improving quality of life if it involves work or even personal activities [13].

In this pillar, the focus of actions is to prevent work-related musculoskeletal disorders by performing: Ergonomic analysis of the workplace, Ergonomic Corrections/Adjustments, Workplace Calisthenics, Relaxation Time, Medical Treatment of Musculoskeletal Injuries; Postural School, Functional Therapeutic Academy and Ergonomic Committee.

PSYCHOSOCIAL

In order to carry out actions aimed at improving the Organizational Climate of the company, Psychosocial care was provided to employees; the results and proposals regarding the surveys on quality of life, stress level and preparation for retirement were analyzed.

It should be noted that the occupational, ergonomics and psychosocial areas perform their actions together so that their goals are achieved, therefore reducing the impact on the Loss Tree of Tucuruí plant.

ERGONOMICS PROGRAM MANAGEMENT

The planning actions of the ergonomics program begin at Excellence Workshop held annually in Tucuruí Strategic Planning for deployment. Strategic planning is based on developing a clear institutional mission, feasible goals and objectives, a perfect strategy and proper implementation [14].

In ergonomics, coming up with the perfect strategy is not easy due to the dynamism of science technology. The actions developed in the program are deployed using the tool 5W2H and accompanied by performance indicators and actions with their respective targets.

Each action follows the planning and execution of improvement cycles made based on the infinite looping, which means: Learning and Innovation. The "infinite looping of learning and innovation" or simply "Infinite Looping" is shown in Figure 3, which was the main method of learning in Tucuruí. The infinite looping integrates the principles of TPM and MEG in two rounds "PDCA" and "CAPD". These are complementary and are used for continuous incremental improvement (kaizen).

The PDCA cycle, also known as The Shewhart Cycle, Quality Cycle or Deming Cycle, is a methodology that has as its main function to be an auxiliary diagnosis tool for organizational problem analysis and solving. Few instruments show themselves as effective as this one in the search for improvement, considering that it leads to systematic actions that accelerate the achievement of better results in order to assure the survival and growth of organizations [15].

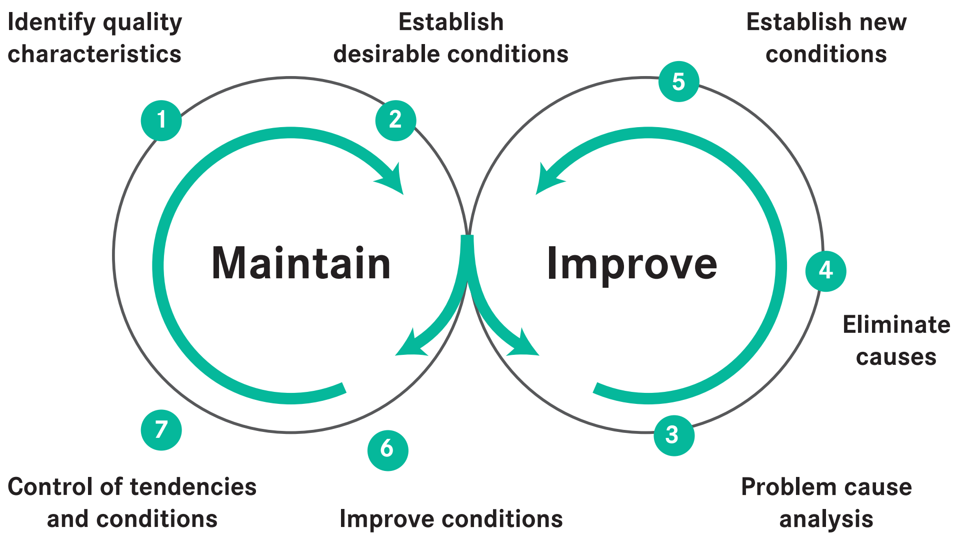

Figure 3. Infinite looping.

The PDCA Cycle has as its main objective to control processes, and it can be used continuously in the management of an organization and in the establishment of control guidelines (quality planning). The CAPD Cycle is a variation of the PDCA one, in which the data analysis begins with the C (check), the suggestion to promote process improvement.

As in figure 3, the innovation and learning process through the "Infinite Looping" follows these steps:

DAILY MANAGEMENT (DO):

- **Identify the current situation:** At this stage there is the state of quality, identifying the existing rules, assessing the degree of compliance by identifying ergonomic non-conformities. Protocols of Ergonomic Analysis of Work are used as an evaluation method. Still at this stage the Losses are established for losses and costs related to health plans, diseases and penalties.

- **Restore to the initial condition to restore the initial state, evaluate results:** On this step the themes of ergonomic improvements in Tucuruí Power Plant are identified. The following are priority issues for improvement according to the risks of the area that will be developed in partnership with the ergonomic committee. Then the plan is established to improve and track the results. It should be noted that improvements are recorded in the database of Focused Improvement Pillar.

- **Management Improving:** This step is related to the management of the master plan of the ergonomics program where actions are deployed for the year in question. There is also the management of ergonomic improvements registered in the database in order to keep it up to date. The management of the implementation of improvements is accompanied by a computerized system and by the ergonomic committee monthly meetings. For the implementation of improvements in Tucuruí, all managers are involved and give the support needed for them to be held under the company's ergonomics guidelines. Replication of ergonomic improvements occurs according to the processes needs. Also, this step manages the key indicators system from the ergonomics program and the implementation of blocking actions when necessary.

- **Track conditions:** Make sure that the rules are visually verifiable and that they will be fulfilled. This step is formed by the critical analysis of the ergonomics program and of its results. Improvement (Check, Action, Plan).

- **Analyze the causes:** In this step, improvement teams are formed and use cause analysis techniques, such as: Whys Analysis, FMEA, brainstorming, Ishikawa, and 5W2H matrix. Tucuruí also uses the ergonomic analysis according to: Moore e Garg, NIOSH, OCRA, REBA, Sue Rodgers.

- **Develop improvements:** investigate of all factors, restore and improve the defects, check results. This step carries out the planning and implementation stages of ergonomic improvements as well as the testing and validation.

- **Establish the new conditions:** review standards. This step is the standardization in accordance with the new ergonomic condition and training where necessary for the stakeholders. When there is equipment with the same characteristics, horizontal replication occurs, and, when appropriate, a patent process is used to register ergonomic improvements.

According to the Infinite looping methodology, in order to manage Daily Activities, one must follow these steps: 1. Identify the current situation, 2. Restore to the initial condition 6. Improve the conditions and 7. Control conditions. To achieve the improvement, or the learning improvement, one must follow these steps: 3. Analyze causes 4. Develop improvements and 5. Establish the new conditions.

3

RESULTS

As qualitative results, the consolidation of a health structure to promote actions based on results can be observed. These are monitored on a monthly basis and retro fed to the program for the implementation of improvements after an analysis performed using quality tools and through the use of the Infinite looping, thus contributing to the achievement of results more quickly. Table 1 presents the results of actions performed in the ergonomics program and emphasizes its results.

As previously mentioned, the result of the Health Pillar, specifically the ones of the ergonomics program, contributed to achieving the overall objective of the plant after reaching the 3% increase on electricity generation availability in the last 3 years. As a result of the consolidation of all these results, the Japanese Institute of Plant Maintenance awarded Tucuruí Hydroelectric Plant with The 2010 TPM Special Award.

KEY PERFORMANCE INDICATORS		UN	ACHIEVED				BETTER
			2008	2009	2010	2011	
ABS_D	Illness Absenteeins index	%	2,62	2,48	2,09	2,00	↑
ABS_{est}	Musculoskeletal	%	11,3	15,2	13,4	2,00	↓
ABS_{Erg}	Non-compliance Ergonomic Solutions Index	%	58,2	68,5	77,0	95,0	↑
ISCO	Climate Satisfaction	%	83,6	84,26	-	84,5	↑
CPS	Health Insurance Costs	%	2,51	2,87	2,59	2,58	↓
ID	Energy generation Availability Index	%	89,79	98,56	92,59	94,0	↑

Table 1. Ergonomics Program Results.

CONCLUSION

Based on this study, it is possible to confirm the significant contributions of the Health Pillar, once the integration of TPM Pillars and a pleasant working environment are essential for Tucuruí Power Plant excellent performance. The prevention activities, based on the rehabilitation of people and team work development, allow the application of the methodology with low investment and high capacity of financial return [16]. It was also observed that, currently, the company intensively uses the concepts of TPM, adopting them in all of its sectors and developing a strong corporate culture based on the principles of this methodology. This is the result of the inclusion of the TPM methodology of Strategic Planning in Tucuruí and of its deployment involving learning opportunities through the application of the Infinite Looping.

The TPM methodology contributed significantly to the management of the ergonomics program and to the implementation of the Health Pillar. It has also improved the Company's development and the Organizational Climate as well as it has directly impacted on the quality of life of employees and boosted overall plant performance.

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An Approach to Promoting Ergonomics at a Systems Level

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ABSTRACT

This paper concerns the building of an ergonomics program that goes beyond the elimination or reduction of workers' musculoskeletal complaints and contributes to the innovation of production processes. It started with tackling musculoskeletal problems. The reduction and elimination of work-related musculoskeletal disorders are important because they improve occupational health as well as increase productivity. The results obtained when solving part of the musculoskeletal disorders as well as a screening process led to the employment of strategies to motivate the adoption of a common "ergonomic language" among all stakeholders. This was done through the creation of ergonomic documents that brought closer together the areas of occupational medicine, law and process engineering, thus facilitating the understanding and management of ergonomic issues, which was corroborated by testimonials of occupational doctors, ergonomists, lawyers and engineers of the researched company. Even the CEO was involved, and a board of Ergonomics was formed. The results show the importance of including three pillars (Normative, Ergonomic Culture and Management) within the ergonomics program through the involvement of a multidisciplinary team. The shortcoming of this research is related to the difficulty in presenting more quantitative data.

Keywords: Ergonomic Management, Ergonomics Programs, Ergonomic Committees, Multidisciplinary Team, Ergonomic Maturity

An Approach to Promoting Ergonomics at a Systems Level

INTRODUCTION

Work-related musculoskeletal disorders (WRMDs) might result from working conditions in which organizational, physical, and cognitive issues are not adequate for workers to perform their activities (Cochran, 2006).

The main direct consequences of WRMDs for the company are increased absenteeism rates, which have negative impacts on productivity, on treatment costs of the professionals suffering from the disorders, and, sometimes, on the expenses associated with compensations due to labour disputes (Moreira and Mendes, 2005).

Reducing and/or eliminating WRMDs is crucial because this will improve occupational health both in industrially advanced countries (IACs) and in industrially developing countries (IDCs) (Zalk, 2001). However, this is a hard, complex task to achieve, especially when the goal is to find solutions that balance out worker's productivity and health.

Productivity is defined in many studies (EANPC, 2005) as the outcome of the formula: productivity = output/input. Input could, for instance, be labour costs, materials and investments and output could be number of products, income, profit or added value. In order to understand productivity, it might be useful to also study other related terms, such as performance or efficiency and profitability.

The terms efficiency or performance can be defined as the relationship between the expected work and the work actually performed (In't Veld, 1975). According to Coelli et al. (2005), one way of measuring performance is to establish the productivity rate, which, according to Sink and De Vries (1984), is the direct relation of the resources that go into an organizational system in a given time frame and the results generated through these resources over that period.

In turn, profitability is a financial term that defines the degree of economic success of a company in relation to the capital invested in it ("Rentabilidade", n.d., September 2017).

The concept of productivity has several aspects and is influenced by the experience of the workers and their environment. Regarding the environment, the following factors have an impact on productivity: workstations, materials, temperature, air quality, ventilation rate, quality and quantity of light, noise, relative humidity, odour, amenities (workplace equipment and accessories), environmental colours and plants (Bakker, 2014).

There is a quantitative and qualitative relationship between productivity, profitability and efficiency (Bakker, 2014). This relationship is experienced by the worker, who is aware of the need to be effective and reach the required goals of productivity so that the company achieves profitability and allows him to keep his job. This is the first view that the worker may have on productivity.

In addition, there is a second view on productivity: some of these workers and their unions claim that the same productivity that ensures employment may also bring about health problems to the workers. This can certainly happen when human capacity is not respected. Sell et al. (2015) state that workers undergoing physically heavy work may have their work capacity and productivity affected. However, it is necessary to demystify the idea that the higher the productivity the worse for the worker's health. Rhijn et al. (2005) clearly showed that changes in the work environment had positive effects on productivity as well as on health. Miguez et al. (2009) also showed that it is possible to simultaneously increase productivity, eliminate ergonomic risk and ensure the health of the worker. The basis for such an assertion is to achieve sustainable productivity, which can be obtained while maintaining the worker's health (Vink et al., 2016), respecting his physical and cognitive limitations during the production process and designing the workplace layout so that he is provided with suitable working conditions. Moreover, preventing discomfort during the work activities stimulates worker performance and contributes to better health within the work environment (Vink, 2004). Vink et al. (2008) also show that for sustainable productivity to be achieved, an approach focused on an individual is less appropriate, it asks for the involvement of many stakeholders as well as for a systems approach (Dul et al., 2012).

This systems approach involving the right stakeholders can be found in the Macroergonomics approach. Several scientific articles prove that Macroergonomics has a positive impact on both employers and employees (Miguez et al., 2017; Larson, 2014; Kleiner, 2008; Holden et al., 2008; Hendrick, 1995). According to Alexander and Orr (2006), many ergonomists apply ergonomic practices, where they learn to identify, analyse and solve ergonomic problems, but they refrain from learning how to design ergonomics programs and, therefore, cannot measure or manage ergonomic results within the company. Moreover, the company also stops after

implementing the improvement as there is a feeling that the job has already been done (Vink et al., 2008). It is important to understand the difference between an ergonomics program and ergonomic practices (e.g. ergonomic analysis of work) because the results of these approaches will invariably differ.

Ergonomics programs are mainly intended to allow for the implementation of ergonomic interventions in a progressive, continuous and organized way. Therefore, an ergonomics program that is aligned with the company policies replaces individual ergonomic actions with a plan of ergonomic priorities involving several areas of the company. Ergonomics programs and their main elements, such as ergonomic committees, are crucial for the establishment of an ergonomic culture within any company (Silveira, 2004). Creating an ergonomic committee in a company is a strategy that gathers professionals from various departments of that company in order to manage the existent and future ergonomic issues (Larson, 2014).

According to Larson (2012), an ergonomics program must go beyond protecting the company's assets by including within its scope elements such as: safety and health of the workers, quality, productivity and the company's reputation. Ergonomics programs such as the ones conceived by Larson (2012) are only possible when the company either has enough ergonomic maturity or is willing to reach it.

Authors such as Vidal et al. (2012) and Guizze (2011) have made valuable contributions to the studies of ergonomic maturity. They have developed models based on information provided by the company's leaders, so they can better guide the ergonomist or the other professional in charge of Ergonomics. Within the field of Ergonomics, maturity can be understood as a tool which aims to measure the scope of ergonomic actions in companies, ranging from the introduction and development to implementation and if these actions are sustainable. The definition of sustainable actions becomes pertinent as we analyse the path that Ergonomics has taken inside corporations, some of which will reach ergonomic maturity and others will not. We can say that ergonomic maturity is a complex phenomenon that depends on several variables such as technical qualification and years of experience of the ergonomist and the moment in which the demand for ergonomic analyses reached the company, be it for preventive or legal purposes. Regardless of the model used to measure ergonomic maturity, success will be achieved once a network of relationships among the different areas of the company has been established and ergonomic committees have been structured around the ongoing participation of their members (Vidal and Santos, 2009).

In this study an attempt has been made to increase the impact of the ergonomist. Companies do not yet consider the ergonomist as an important professional to hold high organizational positions, which sometimes hinders the negotiations (Kuorinka, 1997) and the implementation of an ergonomics program in a full, complete and proactive manner.

The authors propose a new approach on programs of participatory prgonomics involving ergonomic maturity, groups having different purposes of participatory ergonomics and documents that link several areas within a company. The approach is developed and applied in a manufacturing company and evaluated.

METHODS

SETTING OF THE STUDY

This study was carried out in a Brazilian manufacturer (company A) that initially had 700 employees and ended up with 3500 by the end of the research. The total period of research and ergonomic consulting for company A, which is located in the state of São Paulo, Brazil, was 6 years.

DEMAND FOR THE STUDY

Generally, it is the several social actors directly or indirectly involved with ergonomic issues in the company who put forward the explicit demands. However, these demands are sometimes not explicitly formulated, and it is the role of the ergonomist to identify them (Fialho and Santos, 1997).

The demand that motivated the hiring of the ergonomic consulting company belonging to one of the authors was to meet a request by the Public Ministry of Labour. The lack of compliance with that request could incur in high fines based on Brazilian regulatory norms on Ergonomics, such as the NR-17.

One of the authors, a certified ergonomist, worked inside company A for 20 hours a week. At the beginning of the consulting activities, there was no structure in the way Ergonomics was applied, such as Ergonomic Analyses of Work (EAW) or any other ergonomic action program. There were reports of musculoskeletal complaints involving the shoulder, cervical and lumbar regions of workers, showing the need for improvements.

An ergonomics program was developed to contribute to the change in strategies and improve both comfort and productivity at the workplace.

PROCEDURES

Initially, the procedures to be developed focused on guiding and strengthening the ergonomics program, which included: the creation of an Ergonomic Maturity Conceptual Framework (EMCF), the production of two documents – ETOW (Ergonomic Technical Opinion of the Work) and ETOP (Ergonomic Technical Opinion of the Process), as well as the use of a questionnaire of perception of comfort (QPC) to obtain the opinion of the worker after the implementation of ergonomic improvements. Later, the focus was on executing the program and evaluating its effects.

Ergonomic Maturity Conceptual Framework (EMCF)

The EMCF, which is a screening framework, was developed based both on the literature and on the practical experience of the certified ergonomist (see figure 1). This framework links the ergonomic actions usually done in an ergonomically mature company to the actions already carried out by the company. This ergonomic maturity screening is not intended to replace ergonomic maturity models (Vidal et al., 2012; Guizze, 2011), but it uses knowledge from these approaches and it differs from them because it does take into account the whole process of these ergonomic actions, ranging from introduction and development to implementation, as is usually the case in macroergonomic (Hendrick,1995) and participatory ergonomic approaches (Vink et al., 2008). Additionally, a screening framework was developed; this included identifying situations related to the ergonomic history of the company in order to draw a qualitative reference of ergonomic actions and link them to the ergonomic maturity of the company, that is, how much ergonomic knowledge is actually applied compared with the start and other phases. The EMCF employs common categories used in the literature in the field of Ergonomics, classifying ergonomic maturity in low, medium and high (see figure 1). These three categories are specified and characterized within the framework, which helps the ergonomist to understand in which “ergonomic moment” that company is, so he or she can customize the ergonomics program with applicable strategies according to the level of ergonomic maturity of the company.

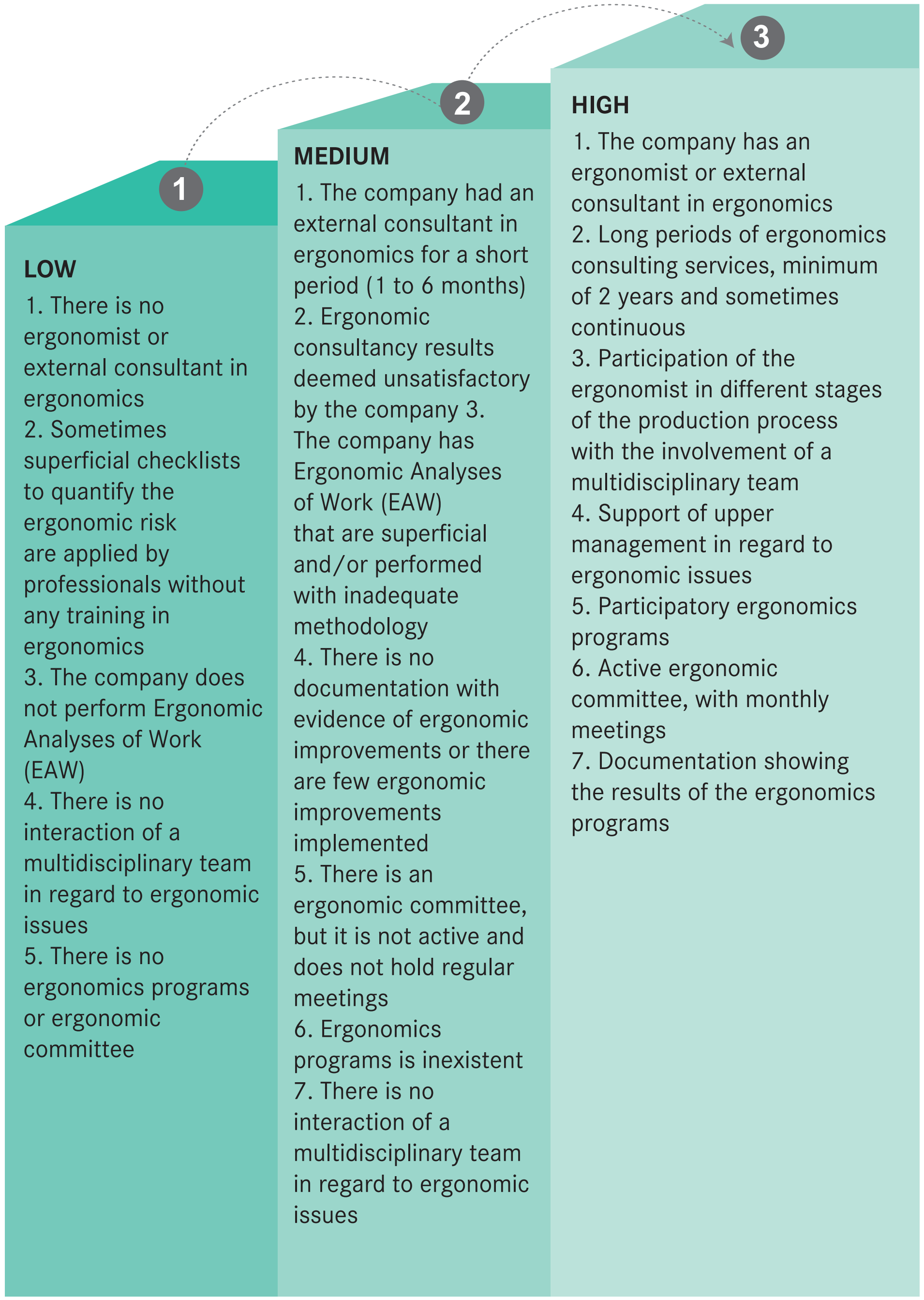

Figure 1. Ergonomic Maturity Conceptual Framework, where the classification low, medium, and high is specified.

The framework also supports the ergonomist in the establishment of parameters that will further allow him or her to build this knowledge when it is still very low or even absent. At the beginning of the ergonomic intervention, a meeting was held with the Human Resources manager, work safety engineer and technician, and occupational physician to get to know and analyse the entire organizational structure of the company and apply the EMCF screening.

DOCUMENTS CREATED TO ESTABLISH AN “ERGONOMIC LANGUAGE”

According to Dul and Neumann (2009), it is important to build a strategy for the “ergonomic language” to be a common language throughout the company. They also highlight the fact that linking Ergonomics to the company’s business objectives, like is done in our approach, is not new. However, in the literature there is limited evidence and few experiments on the possible ways in which this link may be established. Larson (2015) embedded the ergonomics program by defining a focus using Ergonomics to achieve business objectives, such as better health and higher productivity. Effects were measured at the level of health and productivity, but progress in ergonomic maturity was applied in a limited way.

Creating of documents to motivate the adoption of the same “ergonomic language” and bringing together a multidisciplinary team of the company were crucial strategies implemented in this study. These strategies facilitate the taking of actions and the management of ergonomic issues, which will contribute to the ergonomic maturity of the company. Two documents were developed to support the ergonomic growth towards maturity: ETOW (Ergonomic Technical Opinion of the Work) and ETOP (Ergonomic Technical Opinion of the Process).

The Ergonomic Technical Opinion of the Work (ETOW) is a tool used to check if the working conditions are suitable to a sole worker in terms of the kinesiological/biomechanical aspects necessary for the performing of his or her activity. The conditions must attend to the restrictions of this worker in particular situations such as when returning to work from sick leave or specific complaints. Chapter four of this thesis shows the importance of taking the kinesiological/biomechanical aspects into account when assessing worker performance in a given task. This document is crucial because it provides the company physician with information when the worker is returning to work and it also supplies the legal area of the company with evidence to be used in potential labour disputes.

The ETOW does not substitute the EAW (Ergonomic Analysis of Work) because they have different objectives; the EAW, besides considering kinesiological/ biomechanical issues like in the ETOW, also includes organizational and cognitive issues of work in order to categorize the ergonomic risk.

The other document was the Ergonomic Technical Opinion of the Process (ETOP). This document was created upon request of the process engineering department of the company to verify if the new devices, new machinery and the modification and/or design of new layouts were in accordance with ergonomic concepts and with Brazilian regulations.

To support the ETOP, questionnaires on the perception of comfort (QPC) were applied as well. It could be used in, for instance, test prototypes of ergonomic improvements or after implementing other improvements. The format of the questionnaires may change according to the improvement being proposed, but the questions are always intended to check if the user is satisfied or has suggestions to modify or refine the ergonomic improvement.

MODELS OF ERGONOMICS PROGRAMS

The literature describes several models that could be used when structuring an ergonomics program within companies (e.g. Hendrick, 2003; Larson, 2014; Monroe et al., 2012; Cohen 1997; OSHA 2000). The program should not only be described at political and systems level, but it should also offer solutions for concrete problems starting from their creation and development (Silveira, 2004).

According to Kilbom and Petersson (2006), the success of an ergonomics program depends on these important steps: organization of the process, identification and analysis of the problem, development of solutions, implementation of the solutions and evaluation of the results, including an economic analysis. Although corporations seem to face similar problems, the context in which each project is inserted is unique (Kilbom and Petersson, 2006) and, therefore, it requires a customized ergonomics program that takes into account the reality of the company and the way in which ergonomic actions are implemented.

In the current project, a customization of the model of the ergonomics program was applied to company A; this customization also employed knowledge of Lean Manufacturing methodology and thus contributed to the balancing of productivity with worker's health, as it can be seen in the last paper of chapter 5 of this book.

In addition, ergonomics programs should not include solely quantitative issues as they should also incorporate qualitative ones (Dehar et al., 1993).

With that in mind, the authors sought the opinion of the professionals who were involved with the ergonomics program and used the ETOW and ETOP documents. Their testimonials are brought in the results section.

MODEL OF ERGONOMICS PROGRAM OF COMPANY A

Based on the outcomes of the EMCF screening, the ergonomics program was tuned for company A and structured around three main pillars (see figure 2):

1. Normative Pillar
2. Ergonomic Culture Pillar
3. Management Pillar

The normative pillar consists of: the EAW (Ergonomic Analyses of Work); a meeting on the results of the EAW; an action plan consisting of ergonomic recommendations; an implementation of improvements and a validation of improvements through worker comfort perception questionnaires (CPQ).

The ergonomic culture pillar consists of: trainings in Ergonomics for workers and managers; setting up an Internal Commission for the Prevention of Work Accidents and Members of the Ergonomic Committee; Ergonomic Blitz (which is a surprise event taking place a month after the training and through which the ergonomist checks the workstations and, in a practical and individual manner, guides the worker again about his or her postures when performing his or her tasks); several audits aiming at checking whether the Regulatory Norm NR-17 is being observed; an ergonomic improvements book; disclosure of ergonomic information in the company's newsletter and intranet; and an Ergo Development Plan consisting of joint actions of professionals from the engineering and maintenance areas of the company with the external consulting, in order to develop solutions for ergonomic improvements.

The Management pillar content has monthly program overview meetings during which the progress in Key Performance Indicators (KPIs) is monitored.

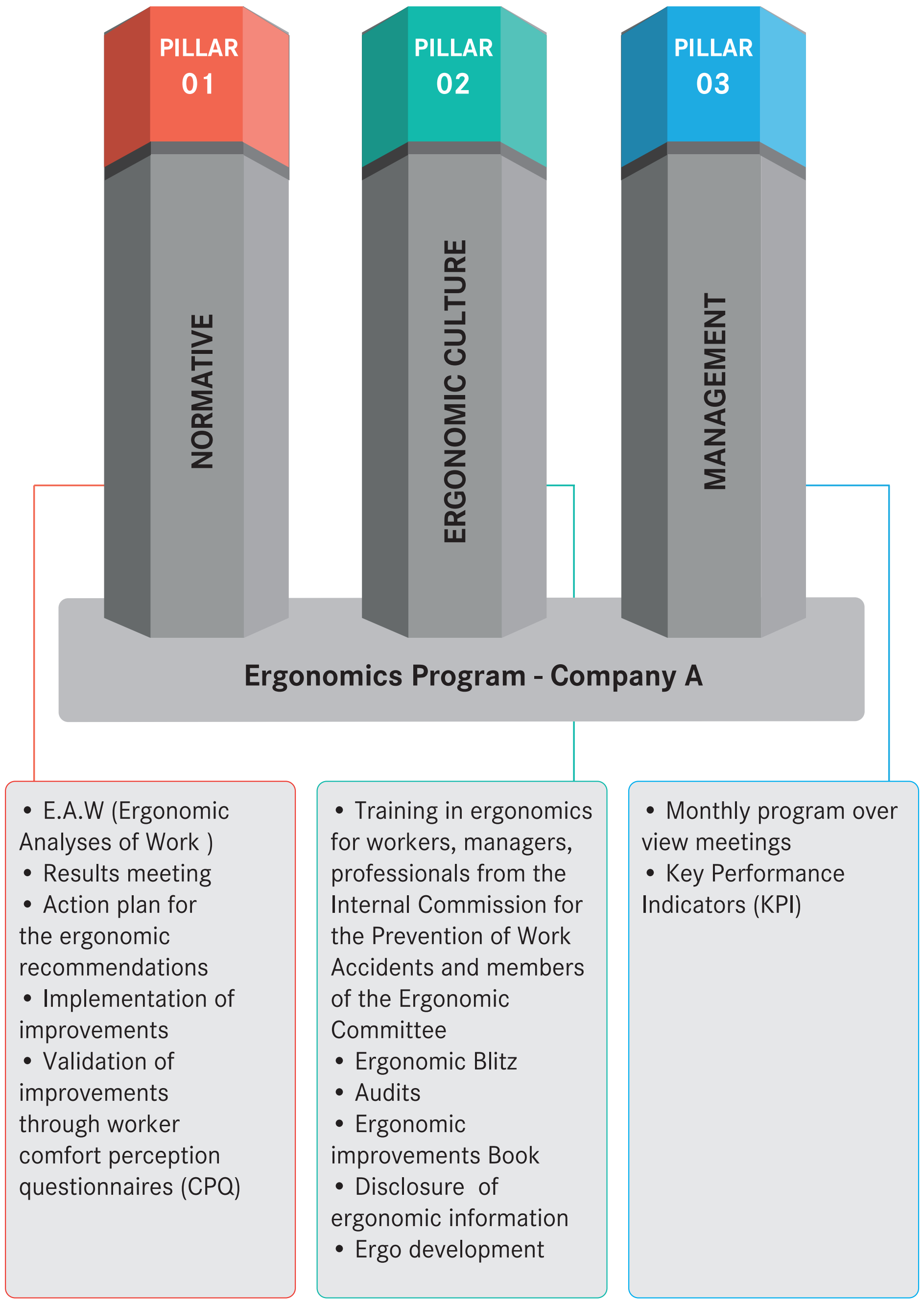

Figure 2. Structure of the Ergonomics Program of Company A.

- **Pillar 1 – Normative:** Usually, Ergonomics is not part of the company's business strategy and attention regarding Ergonomics most commonly arises when there is a need to conform to certain regulations (Dul and Neumann, 2009). The same happened in this study. The initiative started by trying to comply with the Brazilian regulatory norm NR-17 of the Ministry of Labour and Social Security. This norm was created in 1990 in order to "establish parameters that allow for the adaptation of working conditions to the psychophysiological traits of the workers in a way that they are provided with the highest degree of comfort, safety and performance".

The NR-17 is mandatory throughout Brazil and equally enforced in all of its states. In 2007, this norm was expanded to include work at supermarket checkouts (NR-17 Attachment I) as well as call centre workstations. It is important to highlight that one of NR-17 sections (17.1.2) requires the employer to carry out ergonomic analyses of work (EAW).

Other mandatory Brazilian standards may be added to this pillar according to the company's business area and/or the nature of the activities carried out in the company, such as: NR-12, which deals with work safety in machines and equipment as well as for item 12.94, which addresses ergonomic aspects; NR-36, which covers work safety and health issues in slaughterhouses and in the processing of meat and meat products, highlighting the importance of risk management, ergonomic committees, pauses, job rotation, among other common actions in the field of Ergonomics. This normative pillar also includes compliance with international Ergonomics standards such as ISO/TC 159 (International Organization for Standardization).

The actions encompassing this normative pillar are: ergonomic analyses of work (EAW); biweekly result meetings with members of the ergonomic committee to discuss the suggested ergonomic improvements; elaboration of an action plan to follow and implement the ergonomic improvements based on the current legislation and on the needs of the workers; validation of the implementation of the improvements through the application of the questionnaire of perception of comfort (QPC).

- **Pillar 2 – Ergonomic Culture**

This pillar consists in forming an ergonomic committee subdivided into a central committee and sub-committees (see figure 3), with a total of 30 professionals from different areas of the company (e.g. doctors, nurses, physiotherapists, engineers, safety technicians, among others). The central committee was comprised of key company people (managers, safety engineers and technicians, process and innovation engineers and occupational physician). In addition, the subcommittees consisted of a worker from each area. The members of the central committee and subcommittees participated in the meetings scheduled for the participatory ergonomics group that they had chosen. Each member of the subcommittee could take part in one or more groups.

The participatory ergonomics groups were subdivided into six groups with the following activities: 1. Carrying out the Ergonomic Blitz to check the ergonomic issues of the workstation and individually guide each worker (11 people); 2. Audits that helped to verify compliance with ergonomic standards (11 people); 3. Elaboration of the Ergonomics book to record the ergonomic improvements (5 people); 4. Development and monitoring of the Key Performance Indicators (KPIs) of the ergonomics program (1 person). The chosen indicators were the number of targeted ergonomic improvements versus the number of actual improvements as well as the identification of any reduction in and/or elimination of the ergonomic criticality after the ergonomic improvement; 5. Dissemination group with the purpose of publishing ergonomic tips in the company's newsletter, disseminating the concepts of Ergonomics in SIPAT (abbreviation of Portuguese words meaning: Internal week for the prevention of work-related accidents) and coming up with possibilities for Ergonomics to be widely disseminated throughout the company (15 people); 6. Ergo development, in which the professionals of the area of engineering and maintenance, along with the external consultant, developed improvement solutions in Ergonomics (5 people). All the activities of the participatory ergonomics groups were carried out by the members of the central committee and subcommittees under the coordination of the external consultancy in Ergonomics. It should be noted that the professionals received the invitation from their leaders, that the participation of the professionals was voluntary and took place within working hours.

The condition for the members of the central committee and subcommittees to be allowed to join the activities in the participatory ergonomics groups was a 16-hour Ergonomics training given by the external consultant on the company grounds. The training for the 30 people was done in four 4-hour meetings.

Also, a 1-hour ergonomic training was provided to professionals in the area of operations and management who were not part of the Ergonomics subcommittees and professionals from the Internal Commission for the Prevention of Work Accidents received a 4-hour training.

This is one of the most challenging pillars as it involves many people, lots of time, changing behaviour in the company and also getting support from the board of directors with their time and company's resources. According to Smith (2003), ergonomic culture is steady when everyone understands Ergonomics and takes some responsibility for ergonomic issues in the workplace, but this does not happen overnight.

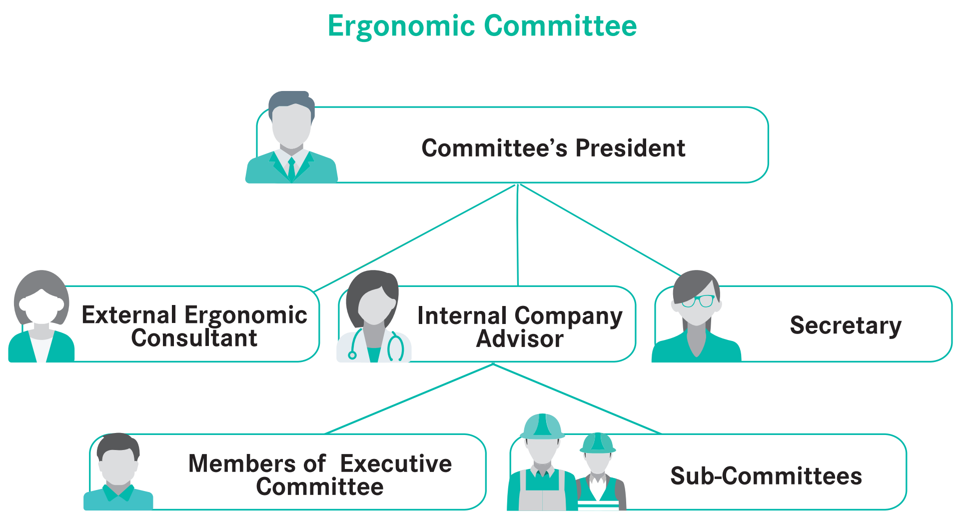

Figure 3. A possible structure of an Ergonomic Committee.

- **Pillar 3 – Management**

In this pillar, the focus is to manage and measure the results of the actions taken under the normative and ergonomic culture pillars in order to verify if they actually led to the improvement of the work environments. According to Abaraogu et al. (2016), the main focus of ergonomic interventions is to make work environments compatible with people's skills and limitations.

Quantifying the number of recommendations for ergonomic improvements versus the number of actual ergonomic improvements was one of the key indicators chosen in this pillar. Another indicator in this pillar was the identification of any reduction in and/or elimination of the ergonomic risk after the ergonomic improvement. As it was mentioned in the previous pillar, one of the activities of the participatory ergonomics group was the development and monitoring of the indicators, which are input for this management pillar.

Briefly, the main objective of pillar 3 was to explain to the company's management the situations that required ergonomic intervention following the ergonomic recommendations suggested in the ergonomic analysis of work (EAW). It is meant to clarify the ergonomic risk found in the assessment of ergonomic risks. The ergonomics program of company A was entitled 3E: expose, elucidate and engage (see figure 4).

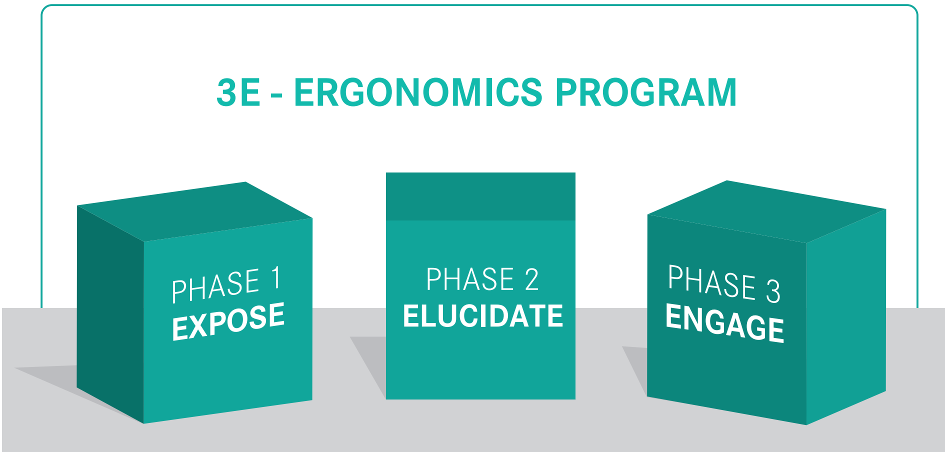

Figure 4 – Goals of the 3E Ergonomics Program.

RESULTS

The categorization proposed by the EMCF allowed the authors to classify company A's ergonomic maturity as low. The proposal regarding the format of the ergonomics program as described above was offered to company A including the 3 pillars. However, in practice, the complete structuring took place only at the end of the 6-year period of the consulting services. In the first two years, due to the limited resources (only a single ergonomist) and the low level of ergonomic culture in the company, the project focused only at supporting Pillar 1, the normative one. This pillar alone is enough to meet the legal demands imposed by the Public Ministry of Labour, a requirement that initially motivated the hiring of the ergonomic consulting services. The company could stop the entire ergonomic project at this point, which is common in most cases in Brazil. However, the company did involve many employees and ergonomic result meetings were held with managers, safety and process engineers, safety technicians, physicians, and workers to discuss, design and deploy ergonomic improvements, building a basis for the continuation of ergonomic actions. The ergonomics program also promoted a good relationship of the company with government institutions, unions and employees.

The establishment of Pillar 2, ergonomic culture, took place in the third year of the consulting services and it was possible due to the involvement of a multidisciplinary team including the ergonomist and the frequent contact with the routine of the company's production process and its ergonomic needs.

Pillar 3 was the last one to be established as it can only be done after pillar 2 is established. Another reason for the delay in structuring pillar 3 is pointed out in the scientific literature as welcome time to set up monitoring systems. According to Dul and Neumann (2009), in most companies, feedback on injury, absenteeism, turnover and other indicators is hardly provided and, when it does happen, it comes with considerable delay.

RESULTS – PILLAR 1 – NORMATIVE

The objectives of pillar 1 were achieved through the accomplishment of 500 ergonomic analyses of work (EAW). The majority of the ergonomic risks pointed out in the analyses were reduced or eliminated through ergonomic improvements, data supporting this claim can be found in all the papers from chapter 5 and the ones specifically developed for this program are reported in the first and third papers from that chapter.

Another situation that supports some of the improvements in pillar 1 is that, during the ergonomic assessment, the company underwent an audit by an expert from the Ministry of Labour. He acknowledged the evolution of the company in the management of ergonomic issues and agreed with the model of the analyses. He concluded his technical opinion with the following words:

"With regard to the assessment of ergonomic risk, the new ergonomic analyses take into consideration the cognitive load and organizational issues using standardized assessment methods that allow quantification of the ergonomic risk for each upper limb used in the activities, which resulted in a comprehensive specification of the ergonomic risk. Thus, I conclude that the company complied with the recommendations."

RESULTS PILLAR 2 – ERGONOMIC CULTURE

One of the most important factors in promoting an ergonomics program is the access to information for all parties focussed on their specific interest (Haines et al., 2002). Often, the main inhibitor of effective sharing of knowledge is the cultural issues of a population (McDermott and O'Dell, 2001). With that in mind, the trainings for the ergonomic committees were fundamental for workers to have access to information on ergonomics, and this, in turn, helped in the strengthening of the ergonomic culture in the company and, consequently, in the consolidation of the ergonomics program.

The training for the 30 members of the committee and subcommittees obtained the following participation rates: 1st meeting 80% participation; 2nd meeting 93%; 3rd meeting 96% and 4th meeting 90%. This participation rate in the ergonomic trainings indicated a genuine interest in the ergonomic issues and contributed to the ergonomic maturity of the company as the participants replicated the ergonomic concepts in the productive environment and became involved in the participatory ergonomics groups of the subcommittee (ergonomics blitz, auditing, recording of ergonomic improvements, monitoring of performance indicators, dissemination and ergo development).

RESULTS PILLAR 3 – MANAGEMENT

The importance of this pillar, which included monitoring of the results in the company, called for the creation of an internal ergonomist position in the company. The consultancy assisted the company in the hiring and training of this new professional in the last year of the provided services.

One of the activities in this pillar, the overview meetings to inform the management of different sectors, indeed took place monthly, in some months with 100% participation and in other months with lower participation rates. Each manager had a one-to-one meeting with the external consultant focusing exclusively on his or her sector. All the information was presented, and this material was sent monthly to the president of the company, whose support was fundamental for the accomplishment of the ergonomic improvements and for the implementation of the ergonomics program. Outcome indicators have been drafted for this pillar, but the publication of their results has not been authorized. What we can say is that the number of improvements implemented was significant and the amount of musculoskeletal complaints decreased significantly.

The following testimonials present a qualitative view on the efficiency of the ergonomics program:

View of the Company's occupational physician on the ETOW:

"The Ergonomic Technical Opinion has proved to be a very useful tool in occupational health management. The instrument allows the technical analysis of the ergonomist and that of the occupational physician to be combined into a single document."

View of the internal new company's ergonomist on the ETOW:

"This tool is very versatile because it allows us to act quicker in the investigation of complaints, allowing for a fast assessment of the ergonomic risk and its relationship with workers' complaints. It is an excellent link between the Ergonomics team and the medical team as well as it enables us to document each professional conduct."

View of the Company's occupational lawyer on the ETOW:

"The Ergonomic Technical Opinion of Work consolidates the arguments presented in the companies' defence hearings because it complements the ergonomic analysis by providing a very personal evaluation of the worker in his workstation through, for example, the confirmation that he has never been exposed to any occupational risk."

View of the company's Process Engineer on the ETOP:

"This technical opinion allows us to spot what our eyes cannot see, besides that, the combination of Ergonomics tools and engineering, especially Lean Manufacturing, is an extremely valuable tool."

According to Silverstein et al. (2006), the involvement of these professionals can happen in different levels and ways within the programs of participatory Ergonomics.

The opinions and suggestions of the professionals described here were discussed and validated during the monthly meetings of the ergonomic committee, and the results observed allow us to say that there was progress in the ergonomic maturity and, according to the Ergonomic Maturity Conceptual Framework (EMCF), we can now categorize the surveyed company with a score that indicates a high ergonomic maturity.

DISCUSSION

Despite the fact that the demand for this study was not anticipated by company A, the results show that Ergonomics is now part of the culture and the business of this company. The intervention of the Public Ministry of Labour through the audits and workers' anonymous complaints has, unfortunately, been the main source of awareness of Brazilian companies in regard to Ergonomics. Ergonomics is an essential component of any program targeting quality of life in a company (Hedge and Pazell, 2017).

In general, this study shows that it is possible to set up an ergonomics program and the results are worthwhile. This case also shows that it takes time. Pillars 2 and 3 could only be started after some years. Certainly, this period is not a rule, since it is necessary to take into account, among other factors, the particularities of each company and the experience of the ergonomist. According to Kilbom and Peterson (2006), ergonomics programs need time to produce results and underestimating this time can lead to failure and misunderstandings can generate resistance and impair the progress of ergonomic actions.

In this study, professionals from different areas and hierarchical levels of the company had access to information on ergonomic concepts in the trainings and in the participatory ergonomics groups, as well as in meetings of the committee and subcommittees. Having access to key information at any moment in time promoted the sharing and sedimentation of knowledge about Ergonomics and culminated in the dissemination of an ergonomic culture throughout the company.

According to Devereux (2008), the culture and productive process of each company are fundamental to determine the structure of programs of participatory ergonomics and the form of analysis.

The experiences of an initial business scenario with a number of 700 workers and the monitoring of the company's growth for up to 3,500 workers allowed us to understand how important it is for the ergonomist to know the production process in order to propose ergonomic recommendations that are in alignment with the dynamics of the company, be it in the designing or in the improvement of workstations. According to Dul and Neumann (2009), the production process of companies is dynamic, therefore, the ergonomist must possess both scientific and practical knowledge in order to propose and follow ergonomic improvements in the most effective way possible.

The insights of this study, such as the creation of the Ergonomic Maturity Conceptual Framework (EMCF) and the creation of documents – ETOW, ETOP and questionnaires of perception of comfort (QPC) – contributed to the ergonomics program being scaled to the Ergonomics knowledge of the company and going beyond the concern with work-related musculoskeletal disorders (WRMD).

It is obvious that eliminating or minimizing WRMDs will always be an important goal of ergonomics programs (Larson, 2012), but going beyond them means bringing Ergonomics into the company's business in order to help it optimize its production processes by associating ergonomic knowledge with methodologies such as Lean Manufacturing and thus contributing to the balancing of productivity with worker's health. As an example of this balance, the ergonomics program described here reduced and/or eliminated the musculoskeletal complaints, created new opportunities for ergonomic improvements and, consequently, resulted in savings with labour disputes regarding occupational diseases. As a rule, when we talk about benefits in Ergonomics we have in mind continuous improvement of the productive process (Rodrigues et al., 2017; Miguez et al., 2017) and worker health (Miguez et al., 2017).

Finally, the ergonomic improvements carried out in the company contributed to a good relationship between the company and its employees, their unions and governmental institutions.

LIMITATION OF THIS STUDY

A limitation of this study is that the researcher who evaluated the program was at the same time the consultant, which could influence the outcomes. On the other hand, shortcomings were reported, such as the long duration, energy it took to set up the program and an internal ergonomist was missing, which was again solved later. An advantage might be that the insight was rather deep, and it was more like an action research approach (Denscombe, 2010). Also, it did not present much quantitative data and perhaps the current approach of the ergonomics program could have been even more effective. However, the qualitative research explained here may contribute to the continuity of future studies on this subject.

CONCLUSION

After showing the need for an ergonomic assessment by of the Public Ministry of Labour, an ergonomics program was set up in a company. The process started locally but grew to a company-wide approach. This approach is described in other cases as well and might be useful for more companies. It is the involvement of a multidisciplinary team and workers from different areas, along with the support of top management, that are the key to achieving positive results, such as those reported in this study.

Moreover, this study could be one more piece of research on the establishment of ergonomics programs, however, what makes it different from other ones is the 6-year period dedicated to this program, its dynamics, and, last but not least, its new approaches on the management of Ergonomics through the creation of documents and the consolidation of an ergonomic culture within the company.

ACKNOWLEDGMENTS

The authors thank the professionals of company A who accepted the challenge of proposing new management approaches in Ergonomics and introduced them in their daily practices.

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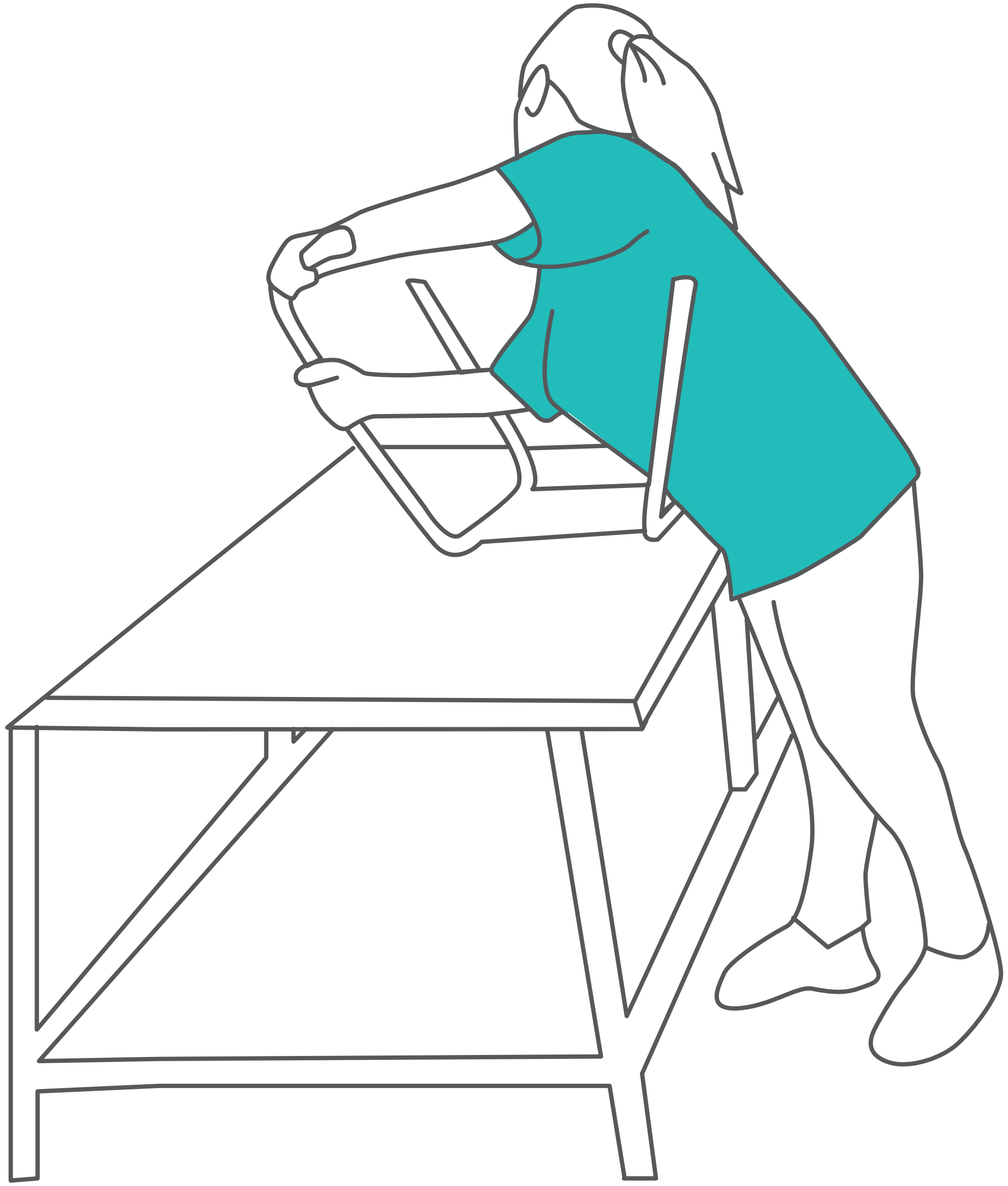

CHAPTER

4

Work Movements

Work Movements: balance between freedom and guidance on an assembly task in a furniture manufacturer

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Springer International Publishing, 2016.

ABSTRACT

This study demonstrates that the ergonomic analyses of work must consider why a worker adopts certain movements (gestures) when performing assembly tasks. It discusses the balance between allowing the worker to freely choose the way of assembling goods and providing guidance. On two assembly tasks in a furniture manufacturer, this research performs an ergonomic analysis in which worker movements are emphasized and it investigates the impact of these strategies on the ergonomic risk and on the worker's health. Data collection instruments included direct observation, unstructured interviews and film footage. The ergonomic analyses show that the work environments are ergonomic, but workers adopt their own movements, unaware that these are awkward postures. Guidance proved to be effective in improving ergonomic risks. This article highlights the significance of understanding work movement, its implications in the corporate training programs as well as in the ergonomic risks and in the worker's health.

Keywords: Ergonomics, Assembly Line, Modus Operandi, Ergonomic Risk, Training, Work-Related Musculoskeletal Disorders (WRMSDs)

Work Movements: balance between freedom and guidance on an assembly task in a furniture manufacturer

INTRODUCTION

In the last decades, many changes have occurred in the workplace. Many of them still happen within the production processes in companies, which are always aiming to increase productivity and provide competitive costs, both while retaining quality.

In Brazil, companies in several sectors fall within this scenario and generate a considerable number of jobs. As an example, one could cite the furniture industry. In 2013, there were 2,580 furniture manufacturers solely in the southern region of the country, creating 44,574 jobs and 93 million pieces of furniture, which were worth 1.8 billion US dollars. The furniture industry in the south of Brazil represents 13.8% of the all companies in the country. In 2015, the revenue of the furniture industry in Rio Grande do Sul was 2.1 billion dollars and the revenue of the domestic market in Brazil was 35.74 billion dollars [1]. Several Brazilian furniture manufacturers have been modernizing their facilities through automation, however, a great deal of assembly line tasks are manual ones and many require ergonomic intervention.

Lim and Hoffmann's studies [2] revealed that research on manual assembly tasks has historically emphasized a) time and motion studies, b) sequence and cognition of assembly tasks, c) subjective difficulty of component assembly tasks, d) effects of the structure of the assembly line on worker's performance, e) personal preferences on the layout of work stations, and f) the impact of following manual assembly instructions on the worker's performance. Despite all of these different research scopes and studies, Lim and Hoffmann [2] believed there was the need to investigate one more aspect within the field: what would happen if the worker could choose his or her own way of working. Hence, the aforementioned researchers conducted a study that revealed that the 40 participants adopted different assembly patterns, even when assembling a simple product.

The different strategies adopted by the worker when performing manual tasks have made us reflect upon and explore the balance between freedom of choice and providing instructions when assembling goods. Moreover, this study analyzed the movements adopted when performing tasks, considering the impacts on the health of the worker.

The complexity of this issue makes us think about the definitions of work movements and those of modus operandi / work style. In addition, it makes us wonder whether these terms are synonyms or different concepts.

According to Pastre e Guimarães [3], modus operandi or work style is the way a worker perform his/her tasks and it may vary according to the experience of the professional. Moreover, the modus operandi may be altered by formal training on how to perform the tasks. On the other hand, Vidal [4] conceives modus operandi as a response of the worker to the need of reconciling the task (request), the means of work and the way of performing the task.

Lémonie and Chassaing [5] define work movements as natural and complex movements that are strategies employed by the worker to respond to work demands. They are a key tool for the worker and possess three important functions: 1. promote efficiency, 2. preserve the worker's health and 3. integrate productivity and quality.

Therefore, it seems clear that both definitions of modus operandi and work movement state that the worker uses his body (arm, torso, head, etc) in order to create regulatory strategies when performing manual tasks so he can respond to work demands in situations where the actual work differs from the one requested. Furthermore, the strategy of adopting movements aims at preserving the health of the worker in terms of work-related musculoskeletal disorders [6].

The literature also discusses the relevance of encouraging workers to identify the "one best movement according to their individual experience when performing the same task. The practical knowledge resulting from this should then be included and shared within follow-up training sessions [5,7]. In this study we employ the term work movement because we see it as being more pertinent to our research.

In April 2015, during a symposium presentation, one of the authors administered a questionnaire about work movements to 18 professionals in the field of ergonomics (physical therapists, ergonomists and university professors). The questionnaire contained 5 multiple-choice questions (Appendix 1) and the results showed that 12 participants declared to have knowledge of work movements and 6 declared to not know about the issue. However, 58% of the subjects believe that work movement is a strategy used to avoid musculoskeletal discomfort and to gain time so production demands can be met.

Besides the conceptual issues, it is pertinent to point out that the queried professionals know about work movements, but do not take them into account when performing their ergonomic analyses of work.

The focus of the majority of ergonomic analyses is on biomechanics and kinesiology; they tend to not take into account the reasons why the movements are performed this or that way. Thus, the present study aims to raise awareness of the importance of movements in task performance, as well as how simple instructions can make a big difference in the ergonomic risk at the workstation and prevent work-related musculoskeletal disorders.

METHODS

The present study was carried out at a large office furniture manufacturer in the countryside of the state of São Paulo, Brazil. The factory is 92,000 ft^2 and it employs 500 people.

CRITERION FOR CHOOSING THE SAMPLE

Initially, we performed direct observation of the activities and informally interviewed the workers from the woodwork and assembly areas in order to select the sample for the research study. Among the 20 workers from those areas, two of them, one from each area, were invited to participate in the study because they adopted different movements from the remaining workers. Both of them were production assistants.

INSTRUMENTS

We carried out ergonomic analyses of the tasks before and after providing the two workers with instructions about the most appropriate movements in the two covered areas, woodwork and assembly. We used RULA (Rapid Upper Limb Assessment), developed by McAtamney and Corlett [8], to categorize the ergonomic risk. This instrument allows for a quantitative assessment of the biomechanical load in the upper and lower limbs, neck and torso of a task. RULA is an assessment instrument recognized by the international system ISO 11228-3- 2006 and its score ranges from 1 to 7 in order to define an action level for musculoskeletal risk.

APPROACH AND RESULTS
JOB CONTENT AND MOVEMENTS

Woodwork area

Description of Task Before Ergonomic Instructions regarding Work Movements. The production assistant gets the parts that have been cut without waiting for the belt to bring them to the edge of the counter. The worker therefore makes movements that are not recommended by the biomechanics and kinesiology studies, namely, he flexes his trunk and reaches to the extreme posture with his arms in order to reach the parts (Fig. 1). It is at RULA level 3: The worker is working in a poor posture, with a risk of injury from it.

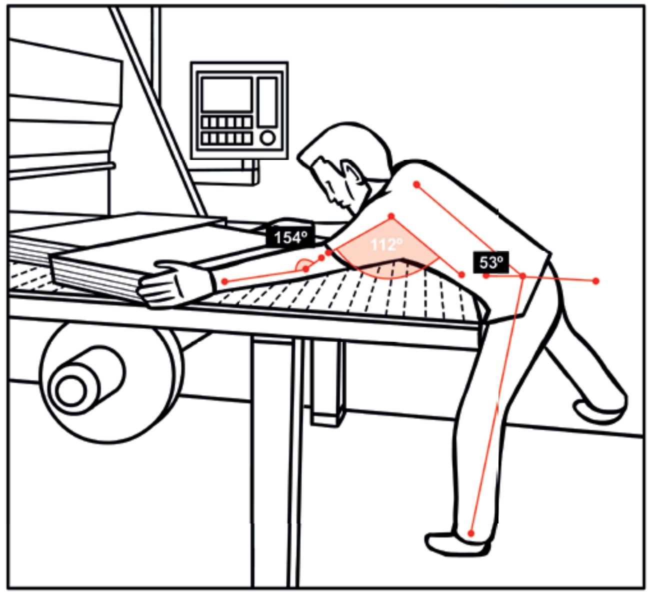

Fig. 1. RULA score Action Level 3.

Description of Task After Ergonomic Instructions regarding Work Movements. After the ergonomic instructions provided by the ergonomist, the worker understood the need to wait for the part to arrive to the edge of the counter. It is clearly noticeable that there is no longer the need to adopt work movements that may contribute to the development of work-related musculoskeletal disorders (Fig. 2). It is rated as a RULA level 1: The person is working in the best posture with little or no risk of injury from their work posture.

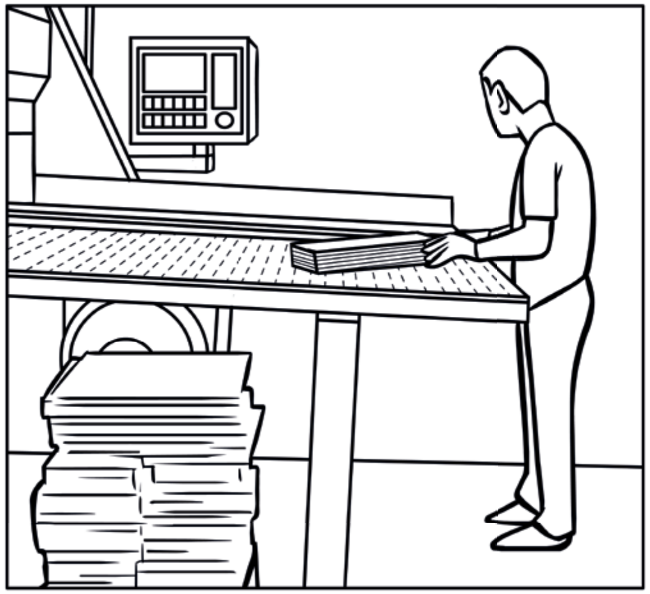

Fig. 2. RULA score Action Level 1.

Assembly area

Description of Task Before Ergonomic Instructions regarding Work Movements. The production assistant places the rubber floor glides on the base of the chair. She adopts movements that are not recommended by the biomechanics and kinesiology studies, namely, she flexes her back and arms in order to perform the task (Fig. 3). RULA score result was Action level 3, indicating that further investigation and changes are needed. In this case, the layout of the workstation is proper and it does not require that the worker use her body – work movements – in order to attend to the production demand.

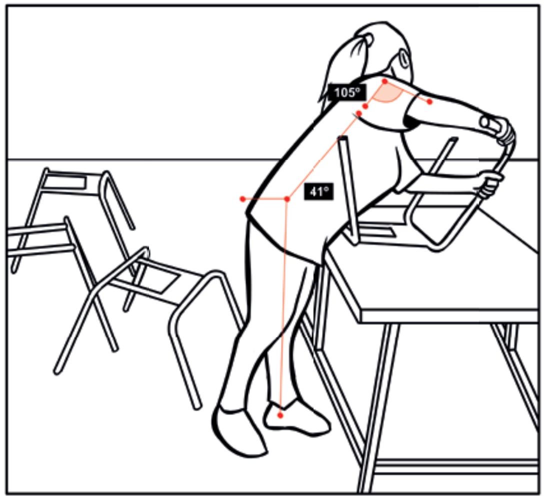

Fig. 3. RULA score Action Level 3.

Description of Task Before Ergonomic Instructions regarding Work Movements. After the ergonomic instructions were provided by the ergonomist, the worker abandoned the movements that did not follow biomechanical or kinesiological standards (Fig. 4). Similar to the woodworking case, the RULA score was Action Level 1, indicating that the posture is acceptable if it is not maintained or repeated for long periods of time.

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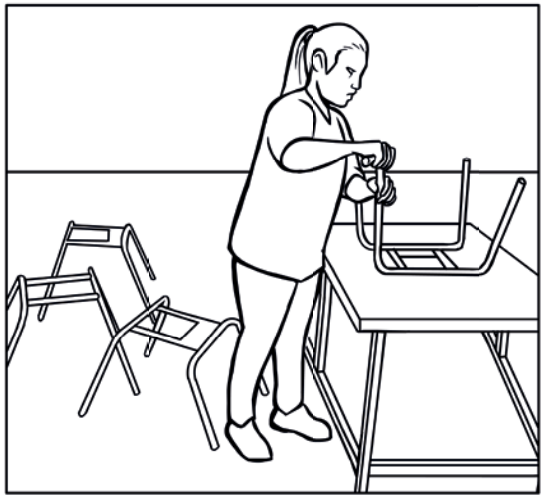

Fig. 4. RULA score Action Level 1.

DISCUSSION

The variability of work movements is fundamental for the worker to be able to respond to task demands [4]. This fact was confirmed in informal, unstructured interviews with the workers, who claim the adoption of those movements' speeds up their work. The work movements analyzed in the woodwork and assembly areas met the production demand but were unnecessary and generated ergonomic risk when assessed through RULA, whose initial, pre-instruction action level score was 3 for both investigated areas (Figs. 1 and 3).

In reality, our observation of the tasks identified a moderate ergonomic risk for shoulders and trunk. Despite the moderate ergonomic risk, found during th ergonomic analysis, we found that only a few workers complained of WRMSDs in their shoulders and trunk. This result is aligned with results from studies published by other scholars. Pastre and Guimarães [3] show that work movements can contribute to explaining cases in which some workers performing the same tasks and having the same production goals complain of WRMSDs in the upper limbs but others do not.

However, most workers in this study are young, which may justify the lack of complaints about musculoskeletal discomforts.

Our experience tells us that, in order for health complaints to be considered WRMSDs, one must also take into account the work cycle frequency in which the movements are made and whether or not these movements are continuous.

The results of this study demonstrate that, at times, the freedom to adopt movements with no ergonomic guidelines may not bring balance between the production demand and the health of the worker.

LIMITATIONS AND STRENGTHS

The strengths of this research are: a) the workers' participation during the entire data collection process; b) the worker's acceptance of the instructions provided by the ergonomist in regard to the need and the possibility of adopting new movements when performing a task; c) the worker's understanding that adequate movements prevent musculoskeletal discomfort associated with work and d) implementation of ergonomic improvements at no cost.

A possible limitation of the study is the relatively small size of the sample of subjects, however, they are deemed suitable for the research object in question.

CONCLUSION

When performing ergonomic analyses, we must take the work movements into consideration and ask ourselves: Why does the worker perform the task the way he does? Do all workers make the same movement(s) when performing this task? Does the workstation layout prevent the worker from making movements that do not compromise his/her posture? Are the movements made in order to meet the high production demand? All these questions must be considered by the ergonomist since each worker has his/her own personal story to perform the work. People arrive at their workstations with their genetic capital, which may contain physical and mental misuse abuse during their lives. They also come with their lifestyle, including aspects involving their personal and ethical conduct and educational background and that will influence the way they deal with their work demands [9].

Based on the results from this study and the authors' experience, we can conclude that:

- When there are problems in the organization of work and in the production process, for instance, work demands beyond the worker's capacity, the variability in work movements are fundamental for the worker to be able to respond to those demands;

- The company must structure its objectives and production goals in a way that the worker can achieve the expected results without resorting to his/her own body (movements) as a regulatory strategy when performing tasks;

- The choice of the worker to adopt movements when performing a task must be complemented with in loco ergonomic training and/or instructions provided by a qualified professional. It is important to point out that providing instructions does not mean standardizing work movements;

- Allowing the worker to perform his/her tasks without previous ergonomic advice may impact the ergonomic risk of the activity and, consequently, the worker's health, contributing to the development of WRMSDs;

- It is not possible to predict all the work movements that the worker will make. Nonetheless, this study demonstrated that it is possible to raise awareness about ergonomic concepts in regard to the adoption of movements that mitigate WRMSDs;

- Ergonomic instructions about movements are efficient and many times cost-free ergonomic improvements, especially if the company employs an ergonomics professional or hires an ergonomics consultancy firm;

- Workers may adopt involuntary movements not required to perform the task. We observed that the workstations in the woodwork and assembly areas were adequate for performing the tasks and did not pose ergonomic risks. It was the voluntary movement spontaneously adopted by the worker that generated the ergonomic risk.

Finally, we conclude by citing Guerin et al one must “understand work, to transform it” [10]. This idea synthesizes the importance and the challenge of considering work movements when performing an ergonomic analysis of work. Besides biomechanical issues, any such analysis must attend to cognitive, organizational and sociotechnical issues involving work and work movements. We believe that the freedom to choose the movements will only be positive if ergonomic guidelines are provided as a balance between the worker’s health with the production demand.

ACKNOWLEDGMENTS

The authors are grateful to all professionals and the furniture company, which allowed us to bring about this reflection over such a relevant issue.

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APPENDIX 1

QUESTIONNAIRE WORK GESTURE

First Name: **Last name:** **Age:**
Profession:

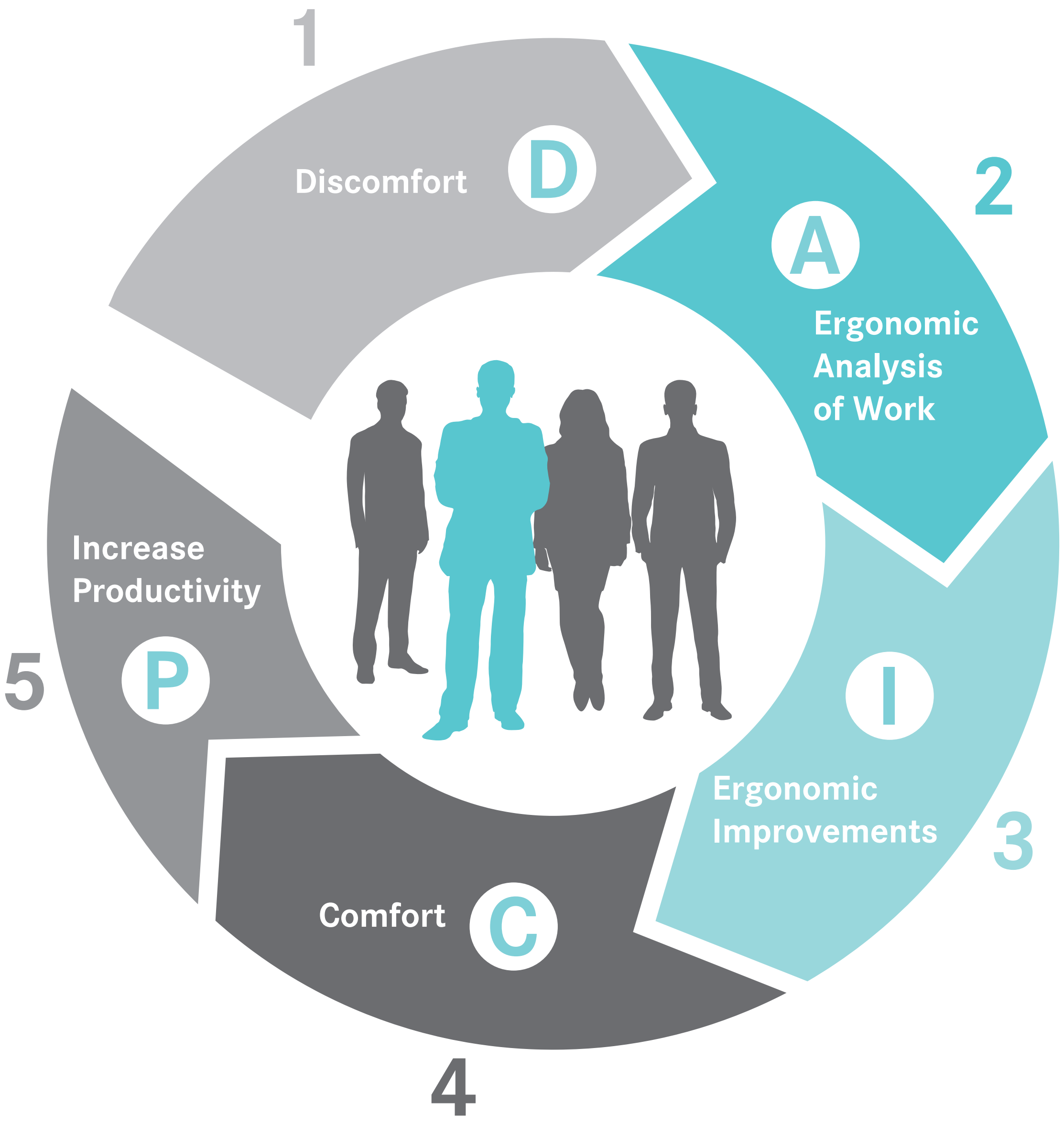
1. How do you define work gesture?
( ) worker's lack of experience
( ) strategy assumed by the worker
( ) company's lack of training

2. You would say that work gesture is:
( ) an strategy used by the company to gain time
( ) an strategy to avoid work-related musculoskeletal disorders
( ) Others / please define:

3. Do you believe the work gesture increases the criticality of the workplace?
( ) No. Why ?
( ) Yes. Why ?

4. Do you believe that work gesture is negative or positive?
( ) Negative
( ) Positive
( ) Others. Please comment.

5. Which intervention strategies do you believe are adequate for work gestures?
( ) Lectures
( ) One-on- one meetings
( ) Others. Please define.



CHAPTER

5

Ergonomic Solutions

Participatory Ergonomics and New Work: reducing neck complaints in assembling

Symone A. Miguez, Peter Vink, Susan M. Hallbeck

Work, 41(Supplement 1), 5108-5113, 2012

ABSTRACT

A participatory ergonomics approach is used to create a new work environment, which is aimed at reducing neck complaints in a cell phone assembly. The participatory ergonomics program included an initiative, problem identification, a selection of solutions, an implementation and evaluation. Twenty-eight women, all operators on an assembly line of cell phone boards, voluntarily participated in the design and evaluation of a device before implementing the device to all 215 employees performing that job. Prior to and after the intervention, RULA, comfort experiences and interviews were used. After introducing an adjustable angled small counter, these measurements showed both posture and comfort improvements. 90% of the 215 workers preferred the new work station and the neck complaints were reduced in 75% of the group. It also showed that the initial prototype needed to be modified as to reduce its sharp edges/compression points for the forearm. This project shows the importance of iterative testing and that an initiative by workers increases the chance of successful implementation.

Keywords: Participatory Ergonomics, New Work, Neck Complaints, Assembly, Comfort

Participatory Ergonomics and New Work: reducing neck complaints in assembling

INTRODUCTION

Work-related musculoskeletal disorders are often found among industrial workers and they contribute considerably to absenteeism [10]. Light assembly work is a clear example of low-intensity work with elevated risks of neck and shoulder disorders [1].

There are indications that a participatory ergonomics approach leads to improvements [9]. Therefore, in this case this participatory approach has been applied to assembly work: assembling cell phones. The cell phone industry currently faces challenges such as high-quality manufacturing, market competition and constant technological innovation. These challenges, in turn, force the sector to continuously alter its production process. These changes are demanding because the industry also needs to incorporate the quality of life for workers in the company.

Implementation of ergonomic improvements can be difficult, but an approach showing successes is participatory ergonomics [9]. Therefore, participatory ergonomics was the strategy used for the development of an ergonomic intervention in a cell phone assembly. The core of the approach is the involvement of people from different company areas for the fostering of general acceptance (buy- in) and direct participation in solving problems. The demand for this study (neck pain) arose from the workers themselves during the ergonomic evaluation carried out by the company's ergonomist. This preliminary study aimed to develop an ergonomic device, called a "small counter", which was based on the user's need and improved iteratively using participatory ergonomic processes. This process resulted in the development of two prototypes before the final version was designed. The final version will be manufactured by an outsourced company and implemented in the focused company.

METHODS

Subjects

Twenty-eight (28) female operators on the assembly line of cell phone boards, between 20 and 37 years of age, between 5'0.6'' and 5'8'' (153.7 to 173 cm) tall and with middle school or better education voluntarily participated in this study. The participants all worked in fixed shifts of 8 hours a day, from Monday through Friday.

Instruments

Ergonomic analysis of the task was done through direct observation of postures, unstructured interviews with the workers, and photographs for later evaluation techniques such as RULA (Rapid Upper Limb Assessment). Comparisons of data before and after the ergonomic intervention were done through RULA, which is "a screening tool that assesses biomechanical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs" [3]. RULA values range from 1 to 7 and they define the action level to be taken, as is shown in table 1:

Action Level	Results
Action Level 1	A score of one or two indicates that posture is acceptable if it is not maintained or repeated for long periods of time
Action Level 2	A score of three or four indicates that further investigation is needed and changes may be required
Action Level 3	A score of five or six indicates investigation and changes are required soon
Action Level 4	A score of seven or more indicates investigation and changes are required immediately

Table 1. RULA's action level and results action.

DESCRIPTION OF THE ACTIVITY BEFORE INTERVENTION

Cell phone board assembly consists of visual inspection, manual insertion of components on the board, board positioning on the jig and soldering of the components using a soldering iron. The work is performed on a horizontal counter which is height adjustable, and the worker statically stands on an anti-fatigue mat. The cycle time of the activity varies according to the cell phone model and the demand of production of the day, alternating between short cycles (less than 30 seconds) and long cycles (greater than 30 seconds) over an 8-hour day. The production layout consists of parallel workstations, where each worker is responsible for finalizing the cell phone board and putting it on the belt that runs between the counters (Figure 1). Although the type of layout described here suggests that the tasks are not monotonous, in this case they are deemed to be monotonous because there are very few technical actions to be performed.

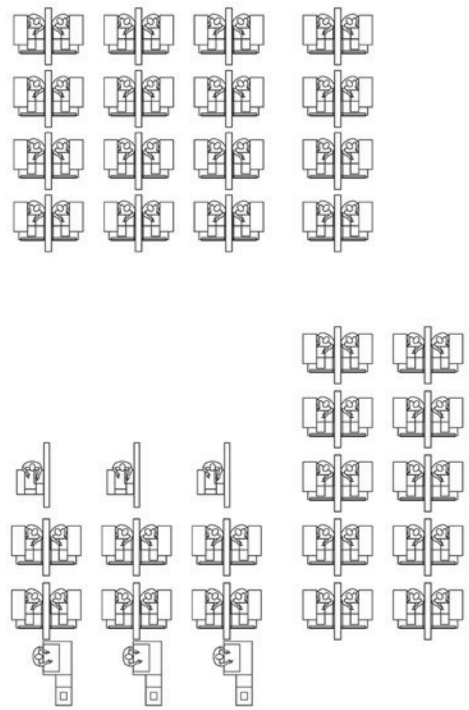


Figure 1. Workstations layout.

APPROACH AND RESULTS

The participatory ergonomics program followed in this intervention and described in this paper consisted of 5 stages: 1. Initiative; 2. Problem identification; 3. Selection of solution; 4. Implementation and 5. Evaluation [9]. This interventional study followed the participatory ergonomic stages in the following way:

Stage 1 – Initiative

According to [5], the initiative may arise from the occupational health department of the company. According to [7], the initiative may also come from the workers themselves or from their union. In the present study, the initiative was generated by the workers themselves during unstructured interviews with the ergonomist during an ergonomic evaluation of their workstations. It should be noted that these ergonomic evaluations and interviews are standard because they are part of the ergonomics program at the company.

Stage 2 – Problem identification

This phase is deemed crucial for specifying and understanding the problem [2, 4]. The problem was identified after the ergonomic evaluation which, at first, found three different situations that could be triggering the neck pain reported by the workers:

a) Many of the workers examined do not adjust the height of their work/task counters;

b) neck flexion occurs in varying degrees among individual operators, and this means that some workers flex their necks more than others, related to the demands of the activity, to the modus operandi and the lack of adjustment of the height of the counter;

c) although the counters do meet the various anthropometric dimensions of workers, extra counter support is needed to facilitate precision tasks when using the screwdriver and soldering iron, as shown in Figures 2 and 3.

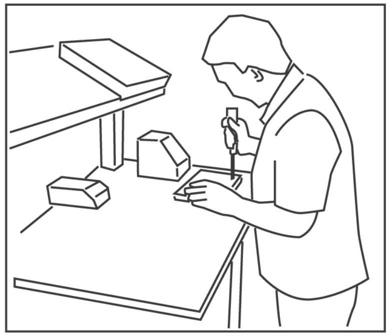


Figure 2. Posture when screwing (before ergonomic device).

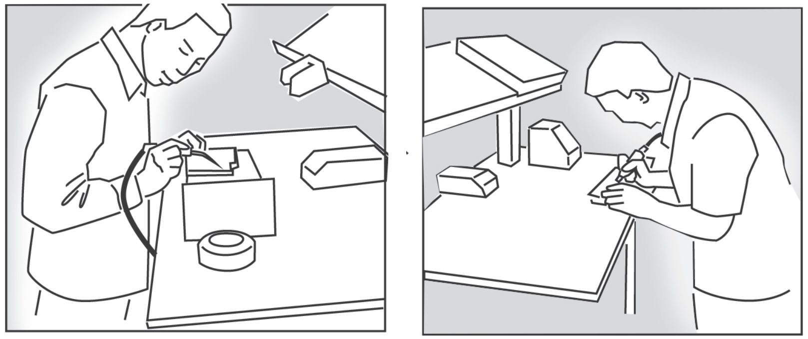


Figure 3. Posture when soldering (before ergonomic device).

Prior to the intervention, RULA was used in order to quantify the problem using direct observation of the postures, photographs and unstructured interviews with workers.

The resulting RULA scores were:

Action Level	Results
Action Level 3 - for the posture adopted when screwing (figure 2)	Score of 5 for the right side assessment, indicating the need to introduce changes soon.
Action Level 3 - for the posture adopted when soldering (figure 3)	Score of 6 for the right side assessment, indicating the need to introduce changes fairly soon.

Table 2. RULA Scores prior to intervention.

Stage 3 – Selection of a Solution

After identifying the problem in stage 2, an ergonomic device ("small counter") was developed. Its purpose was to reduce neck flexion in the tasks of screwing and soldering. It was found that the screwing tasks were best performed on a horizontal surface and the soldering task would benefit from a sloped counter, as this slope would encourage more upright neck postures and more neutral positions of shoulders, arms and wrists. Taking these facts into account plus the fact that there

were few financial resources for the development of an ergonomic device, this device – the first prototype of the small counter - was produced with pieces of PVC pipe and MDF boards (all of which could be found in the company waste). Prototype 1 allows the worker to adjust the inclination of the small counter by pushing a lever to position it horizontally (Figure 4) or in a sloped position (Figure 5).

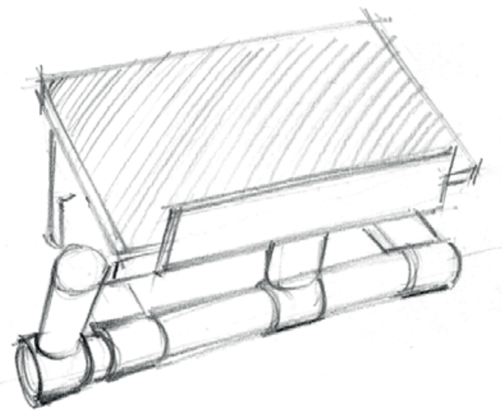


Figure 4. Sloped position of small counter.

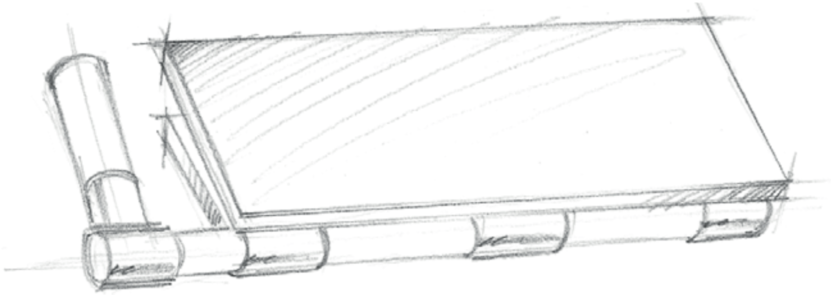


Figure 5. Horizontal position for small counter.

Prototype 1 solved the problem of the neck angle. However, in any intervention, it is extremely important to test any device in real working situations [7] and to re-evaluate the outcome. As suggested in the literature, an evaluation of prototype 1 was carried out through unstructured interviews with 28 female workers who used the ergonomic device (prototype 1) for at least 2 hours a week on the cell phone board assembly line. All 28 workers reported an improvement in the posture of the neck, but discomfort in the forearm from resting them on the new counter, due to a raised edge at the front, which was necessary to prevent the jig from slipping down when the small counter was inclined, as shown in Figure 6.

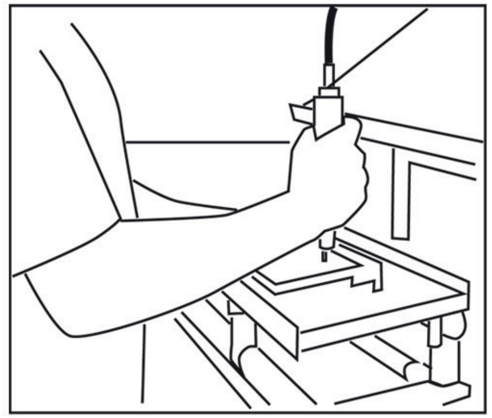


Figure 6. Prototype 1, with raised edge at the front causing forearm discomfort.

Even though the concept of comfort is subjective and there is no universally accepted definition of comfort [6], one should never disregard the opinion of workers in a participatory approach developing an ergonomic device. Additionally, compression points may create new ergonomic hazards for the workers. Therefore, the reports from the workers who tested the device were taken into consideration and prototype 2 was developed. The difference in prototype 2 from prototype 1 was in the front cut, whose raised edge had been removed from where the forearms rest to avoid discomfort and compression points as shown in Figure 7. The development cost of the small counter was U$9.63 dollars per unit.

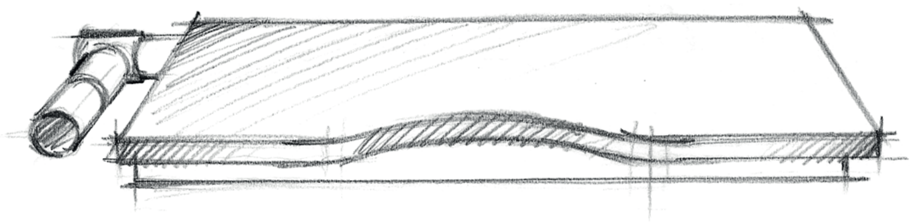


Figure 7. Small counter without raised edge on forearm rest.

Stage 4 – Implementation

The workers were given individual guidance by the ergonomist on how to use the small counter. Prototype 2 was tested and accepted by the 28 operators and will be implemented in all workstations in the assembly line of the company. Approximately 215 professionals will now have the benefits of an improved workstation. The postures adopted while using the new prototype 2 small counter devices are better than prior to the intervention, as shown in Figures 8, 9, 10 and 11.

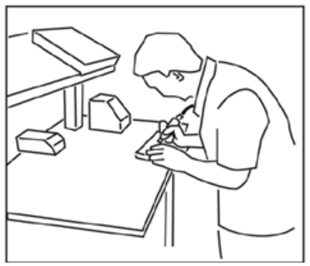


Figure 8. Posture when soldering before ergonomic device.

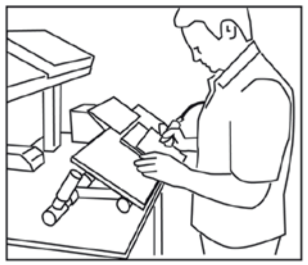


Figure 9. Posture when soldering after ergonomic device.

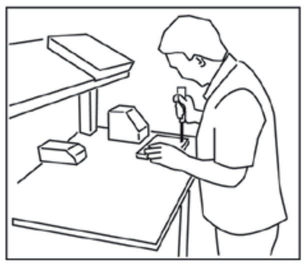


Figure 10. Posture when screwing before ergonomic device.

Figure 11. Posture when screwing after ergonomic device.

Improvement in the worker's postures was verified by means of applying RULA to assess a worker using the small counter using prototype 2. The results were:

Action Level	Results
Action Level 1 - for the posture adopted when screwing (Figure 8)	Score of 2 for the right side assessment, indicating that the posture is acceptable if not maintained for long periods of time.
Action Level 2 - for the posture adopted when soldering (Figure 9)	Score of 3 indicates that new studies are needed and it may be necessary to introduce changes

Table 3. RULA Scores after intervention.

Stage 5 – Evaluation

According to [4], feedback gained from each phase is essential for correcting and modifying the design process, if necessary. Changes in the original ergonomic device (prototype1) were performed and resulted in prototype 2. This tested intervention will be implemented for the entire cell phone board assembly workforce. New interviews will be conducted with workers who have not yet tested the device in order for the evolution of results to iteratively take place with potential updates to the design of the intervention. While the concept of comfort was instinctively taken into account by the workers when deciding to employ the new workstation, which resulted in fewer complaints of neck pain; 10% of the workers worried about the productivity factor. This group reported that the small counter was too large and took up all of the counter surface, which made it difficult to place the other components (table 4).

215 workers	
Percentage of workers using the new workstation is	90%
The new workstation is preferred by	workers between 165 cm and 173 cm tall
Comfort is improved by	Tilting the small counter during soldering and making it higher and horizontal during screwing
Neck complaints are reduced by	the decrease in the flexing angle of the neck and of abduction of the shoulders

Table 4. Overall results.

DISCUSSION

This study is an example of how participatory ergonomics can contribute to practical, inexpensive solutions that meet the needs of the worker and reduce neck complaints. Support from the management, from the Environment, Health and Labor Security, from the employees who voluntarily tested the prototypes and in particular from the maintenance technician who developed the device with us was crucial for this study and change to happen. Within our research, the main change was the posture of the workers, which can be observed in the pictures. The small counter intervention allowed workers to adopt better working postures during the screwing and soldering tasks. RULA also confirms the visible difference in postures by decreasing the scores for screwing and soldering from 5 and 6 before intervention to 2 and 3 after intervention, respectively [3]. Workers who tested Prototype 1 gave positive feedback, which made us modify the design of the small counter in terms of reducing its sharp edges/compression points for the forearm. The same workers tested Prototype 2 and made more suggestions, which allowed us to develop two small counters, with different lengths (one being 23cm x 20cm and the other being 36cm x 20 cm); this makes it possible for them to be adjusted to the different jig sizes and not take up too much space on the workstation, which should satisfy those 10% of workers concerned that the size of the counter might reduce productivity. The good acceptance of this ergonomic device by the workers has encouraged us to implement small counters for workers in other areas within the company, thus benefiting over 1,000 employees. It has also compelled us to establish a partnership with companies specialized in developing ergonomic products so they can manufacture the small counter on a large scale for similar industries.

CONCLUSION

All phases in the participatory ergonomics approach described by [9] are used in this approach (an initiative, a problem identification, a selection of solutions, an implementation and an evaluation). This approach resulted in the reduction of ergonomic complaints. Perhaps the most crucial element in the process was the fact that the workers took the initiative, which resulted in a better work place according to 90% of the worker population. In summary, it is important to note that, in this first phase, we did not aim at measuring productivity improvements. Nonetheless, when informally asking workers about this factor, we were informed that there was not significant reduction in productivity. Thus, we are expanding our research to start manufacturing the final prototype through a partnership with a company that makes ergonomic accessories. This way we are able to demonstrate that participatory ergonomics is a great ally in improving comfort issues within the work environment, facilitating the productive process and preventing musculoskeletal disorders.

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Participatory Ergonomics Generates New Product to Assist Rural Workers in Greenhouses

Symone A. Miguez, Peter Vink, Susan M. Hallbeck

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ABSTRACT

The purpose of this paper is to show that the conjunction of participatory ergonomics and outside consulting can be the link among professionals from different areas. This association can result in improvements in the workplace as well as in the production process. Employing participatory ergonomics, an intervention described in the present study reduced the risk of musculoskeletal disorders and increased productivity while also allowing great rest time through the development and deployment of auxiliary devices and job redesign for the gathering of begonia seedlings.

Keywords: Participatory Ergonomics, Neck Complaints, Assembly, Comfort

Participatory Ergonomics Generates New Product to Assist Rural Workers in Greenhouses

INTRODUCTION

Activities in rural areas in developing countries still receive very little investment in ergonomics. This fact has led to an increase in the number of work-related musculoskeletal disorders in this sector. Repetitive movements associated with static posture, intense rhythm and sometimes weight lifting and transporting are good enough reasons for seeking improvements in the workplace. According to Vink, et al. (2005) implementing changes can be very difficult because they must show the employer an increase in productivity as well as provide comfort to the worker. In light of these difficulties, an outside consultant in ergonomics used participatory ergonomics as a strategy for this study. Through participatory ergonomics, workers in various sectors and levels seek and/or approve solutions for improvement (Seim, 2008). The development of two types of auxiliary devices by a multidisciplinary team (ergonomist, industrial nurse, physiotherapist and process engineer) for the harvest of begonia seedlings and the reduction of musculoskeletal risks will be shown in this article.

METHODS

Subjects. The volunteer participants of this study were 25 workers from the operational area of a large company in the agri-floral sector, with basic schooling, between the ages of 18 and 40, all female. Assessment Instruments. The ergonomic analyses of the tasks were done through direct observation. Data collection devices included unstructured interviews with the workers, as well as pictures and film footage of the workplace. Rodgers et al. (2004) assessment was also used to evaluate the level of effort and effort time per minute; thus, allowing for comparison of results from before and after the utilization of the begonia seedling cart intervention. This instrument enables one to obtain the risk factor for each body part and yields a score of low, moderate, high or very high ergonomic priority (Rodgers et al., 2004).

Description of activity before intervention. The gathering of begonia seedlings is performed in a greenhouse with a controlled temperature of 28ºC and relative humidity of approximately 70%. Workers collect the seedlings while in a standing posture (Figure 1).

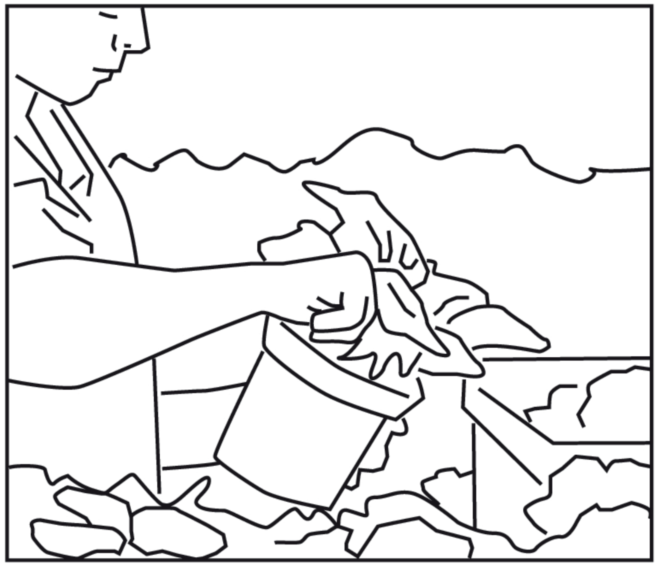

Figure 1

This activity begins with the removal of a begonia pot from the height adjustable table (0.85 to 0.95cm) placed in front of the worker, who generally holds it with her left hand. The worker identifies the seedling which will be removed and removes it with the aid of a utility knife. Once the seedling has been removed, it is placed in a box that is located on the worker's right side. She then manually counts the seedlings in the box, which will later be taken to the cooling chamber. Bad seedlings are discarded in a container on the ground. Then the worker puts that begonia pot back onto the counter, returns the irrigation hose to its original position, and takes another pot. The cycle time for this activity varies due to different pots, ranging from 26 to 29 seconds. The average production rate for this task is 137 seedlings / hour / person. It is important to emphasize that the workers do not spend all eight hours on the task. They take regular breaks, such as a 60 minute lunch, two 10-minute coffee breaks, a 15 minute labor fitness session and free toilet time.

Rodgers Assessment results before intervention. The analysis of the task of holding the pot with the left hand demonstrated a very high ergonomic priority for the arms, elbows, wrists, hands and fingers, and low ergonomic priority for the other body parts, as shown in Table 1. Thus, an intervention, via redesign and development of new fixtures and procedures, is justified by the scores yielded by Rodgers et al. (2004) assessment criteria.

RESULTS

5

The suggestions for improvement arising from the ergonomic analysis were discussed with the production team members via participatory ergonomics and the resulting recommendation to develop a device – which prevents the worker from holding the plant pot in her hands and creating static postures – was accepted and implemented by the company in three months.

Intervention. The design and development of an auxiliary device (Figure 2) was suggested so that the worker would not adopt a static posture while holding the pot in her hand, therefore improving the retrieval of the pots and consequently preventing musculoskeletal disorders. It was at this point that the process engineer, along with the industrial nurse and the ergonomist, developed the first auxiliary device.

This device can easily slide between the plant aisles and fits on top of the tables. It has an adjustable support for the pot and two boxes, one for the good seedlings and the other for the discarded ones. The prototype for this cart was tested and approved by the workers; however, the cost to replicate the device for other sectors was still high. Something else to consider was the fact that the workers still needed to remove the trays from the device and carry them to the cooling chamber. Therefore, a second prototype device was developed based again on participatory ergonomics. It was called the seedling cart (Figures 3 and 4) and it could be easily taken to the cooling chamber. It has a foot support, it is adjustable and inexpensive (approximately US$13.00 each).

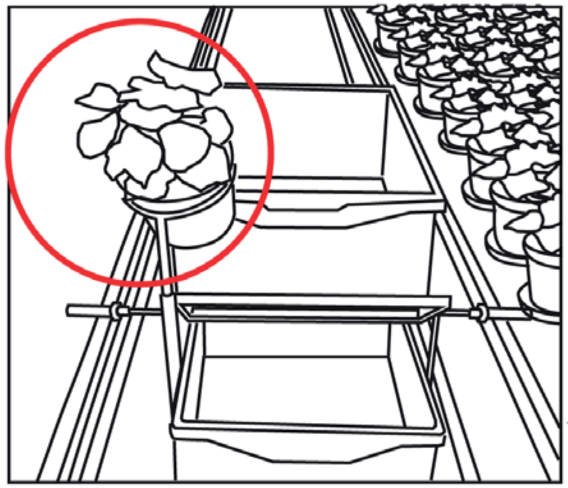

Figure 2

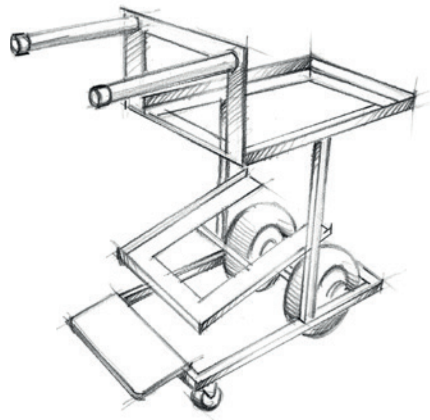

Figure 3

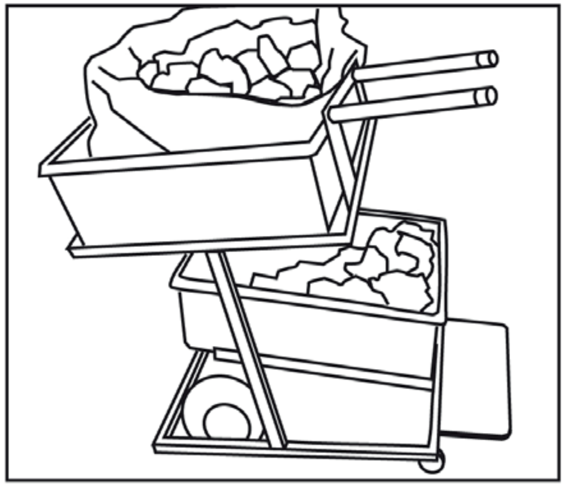

Figure 4

Description of activities after the intervention. While discussing the problems of the job and potential solutions, another intervention was suggested in addition to the cart.

It is no longer necessary to place the irrigation hose in the pot. The irrigation is now done automatically, which is an improvement that places the hose directly on the pot plate.

Thus, the intervention in the gathering of begonia seedlings changed two aspects of the task, namely, the irrigation and worker postures. The improvement of the irrigation combined with the seedling cart improved the posture adopted by the worker to perform the task. Previous potentially high-risk movements and postures, such as upper body flexion over 90 degrees and static hand posture are no longer needed. In addition, the cycle time (holding of the seedlings) has decreased and the productivity (measured as seedlings/hour/person) has increased.

Rodgers Assessment results after intervention. As evidenced by Rodgers, et al. (2004) assessment criteria, the task of holding the pot with the left hand yielded a rating of low ergonomic priority for all the body segments on the left and right, as shown in Table 1. The neck risk factors have not changed. Therefore, since it has improved the work conditions at the begonia greenhouses, the development of the seedling cart is justified.

	Factor/ Location	Before Intervention	After Intervention
Risk Rodgers Score	Neck	moderate	moderate
	Right shoulder	low	low
	Left shoulder	very high	low
	Upper back	moderate	low
	Right upper Arm/forearm	moderate	low
	Left upper Arm/forearm	very high	low
	Right wrist /fingers	moderate	low
	Left wrist/fingers	very high	low
	Other body parts	low	low
Productivity	Cycle Time Range (sec)	26 – 29	13 - 20
	Seedlings/hour/person	137	290

Table 1. Comparison of the Rodgers score risks and productivity before and after intervention.

DISCUSSION

While this study was not intended to be a product redesign project and therefore, does not consider the typical steps in designing a product such as studying the concepts, basic design, construction of a prototype, creating a production pilot project and scale-up (Guimarães, 2004). In fact, this study originated in order to meet an immediate need for activity improvements to prevent musculoskeletal disorders. The product redesign and the elimination of a difficult and unnecessary task (irrigation hose movement) grew naturally from the participatory ergonomics procedure. The stages of product development (seedling cart) occurred in an informal manner with the involvement of the multidisciplinary team and end users/workers. The interventions increased comfort and reduced the musculoskeletal risks to the workers while increasing productivity and decreasing cycle time. In conclusion, the ergonomic solutions that arose from the participatory ergonomics methodology both met the needs of the employees and as well as those of the employer and improved the production process.

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New Ways of Working in a Notebook Manufacturing

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Springer International Publishing, 2012.

ABSTRACT

In order for manufacturing companies to increase the productivity and the quality of products, they need to incorporate the quality of life of workers in their production process. However, this cannot be done without difficulty, especially when there is no budget for ergonomic improvements or people specialized in ergonomics. Thus, this study was developed to show new ways of working; it was carried out in a multinational company in Brazil, it lasted two months and had four steps. The first step of this study involved a 16-hour training for maintenance technicians of the company. The second step consisted in inviting two maintenance technicians to develop ergonomic devices for the notebook sector. The third step was to allow these technicians to identify opportunities for ergonomic improvements in the area. The fourth step was to develop, partnered with the technicians, ergonomic devices at no cost, using existing material in the company, such as MDF boards and pieces of tube pipe. The first ergonomic device was a garbage collection tipping cart. This device facilitates the collection of garbage, preventing movement of the shoulder above 90 degrees. The second ergonomic device was a cart to separate and distribute notebook labels. This device has decreased the time of separation of the labels by 30% and removed the manual loading of boxes. In order to check posture improvement, RULA instrument was used before and after the implementation of the ergonomic devices. The conclusion of this study showed positive outcomes, increasing the quality of life and productivity of workers. We can say that the training was the basis for the success of this study, but what about the new way of working? For us the new way of working in manufacturing provides for exchange of knowledge that can be translated into two words: Ergonomic Team.

Keywords: Notebook, Manufacturing, Design, Ergonomic Device

New Ways of Working in a Notebook Manufacturing

INTRODUCTION

The impacts of globalization and the easy access to technology have changed both work relations and environments. Flexible working hours and home office are ever so common in our day-to-day. This novel panorama may be described as “New Ways of Working (NWW)” and it consists of changes within four aspects of work: 1) physical space, 2) technology, 3) organization and management, and 4) culture at work (Block et al., 2012). The aim of this paper is not to discuss the aspects of these transformations but to demonstrate that in order for one to have the technology needed for the NWW, one cannot refrain from investing in the quality of life of workers in the electronics industry, who need to produce more and more computers in order to meet the increasing demand for these devices. The sales of notebooks in Brazil has been growing every year. The Brazilian Association of the Electronics Industry (ABINEE) estimates that the trading of computers will reach 16.7 million units in Brazil in 2012, which represents a growth of 9% when compared to the previous year, when 15.3 million units were sold. From this amount, 6.2 million units correspond to sales of desktop computers whereas the sales of notebooks and netbooks reached 9.1 million (ABINEE, 2012). The preference for notebooks and netbooks is ascribed to the accessible prices and mobility of these devices. The present 4-step study was initiated due to this universe that comprises the high productivity of notebooks, lack of funding granted to ergonomic investments and the willingness of maintenance technicians to acquire knowledge about ergonomics. The first step included the training of two professionals from the maintenance area who joined the task force called “Ergo Development” within the ergonomic committee of the company. The remaining steps provided the new members of the committee with opportunities to apply their recently acquired knowledge in ergonomics, which resulted in two ergonomic devices. The first device was designed to collect recyclable material and the second one was made in order to facilitate the distribution of notebook labels in the assembly line. Both devices prevent work-related musculoskeletal disorders.

METHODS

The place where this study was conducted was a 3000-employee company in the electronics industry in Brazil. Workers volunteered to participated in this research, which lasted two months and was divided into 4 steps for didactic purposes.

STEPS OF METHOD

Step 1: Training

The 16-hour ergonomic training for the members of the ergonomic committee at the company takes place once a year. It is divided into four 4-hour sessions once a week and it is carried out by an outsourced ergonomics consultant, who possesses ergonomics certification. In addition to the basic concepts of ergonomics, the concepts of anthropometry are widely disseminated in order to meet the practices of the maintenance area. According to Dall'Oca & Sampaio (2001), educational actions possess a potential that is accommodative at times and transforming at others. It is the perspective of transformation that stimulates discussions as well as pro-active attitudes regarding the health of the workers. In face of these statements, we have decided to stimulate changes in people's behavior by suggesting a new way of working.

Step 2: Invitation to the maintenance technicians

Silverstein & Carcamo (2006) report that the modifications in productive environments are usually made by engineers and maintenance technicians. Therefore, inviting these technicians to join the Ergonomic Development group in the ergonomic committee after training was a fundamental milestone for the development of this study. Staff members were motivated by the training and willing to put their knowledge into practice. The technicians were personally invited by the ergonomist to participate in the development process; she informed them that all the ergonomics activities would take place during regular work time, that no overtime would be necessary and that it was approved by both the management and coordination areas.

Step 3: Identification of improvements in the notebook sector

After participating in the ergonomic training, both maintenance technicians chose the place where the ergonomic improvement should occur. There was no specific demand such as musculoskeletal complaints or requests from workers in order to select the activity in which the ergonomic intervention would be carried out. However, the choice could not have been more appropriate because we usually

focus on ergonomic improvements within the production cells or assembly lines and tend to neglect those activities that give support to the production process itself.

If we paid more attention to the support areas, we would notice how these are essential and may end up being the solution for drawbacks in the production process.

Step 4: Development of ergonomic devices

Two ergonomic devices were developed (cases 1 and 2) in order to bring about a practical ergonomic intervention. Leftover materials such as MDF and pipes were employed, aiming at minimizing costs and recycling materials, thus contributing to sustainable actions.

Subjects:

Case 1: A participant of this study was a general services assistant in the notebook production, male, in his fifties, 1.67m tall, with primary education. The subject works in fixed shifts of 8 hours a day, from Monday through Friday.

Case 2: Another participant of this study was a notebook assembly line operator, male, in his mid twenties, 1.75m tall, with secondary education. The subject works in fixed shifts of 8 hours a day, from Monday through Friday.

Instruments:

Case 1 and 2: The ergonomic analysis of the task was done through direct observation of postures, unstructured interviews with the workers, and pictures. Comparisons of data before and after the ergonomic intervention were made through RULA (Rapid Upper Limb Assessment), which is "a screening tool that assesses biomechanical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs." (McAtamney & Corlett,1993).

CASES

CASE 1 - GARBAGE COLLECTION TIPPING CART

Description of the activity before intervention: The activity of collection of recyclable waste material throughout the six notebook assembly lines is performed several times a day by a sole general services assistant. The tasks involved in this activity are:

1) place a large paperboard box onto a cart, see figure 1;

2) walk along the entire notebook area and collect the recyclable waste;

3) deposit all collected material into an exterior dumpster for recycling and reinitiate the activity. There are no determined cycles for these tasks because the worker is responsible for establishing his own pace of work.

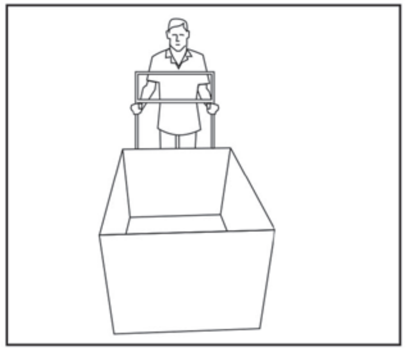

Figure 1. Cart for the transportation of recyclable material.

Description of the problem before intervention: The large amount of material deposited in the cart rendered its removal to the external dumpster a hard task. In addition, the worker needed to move his shoulders above 90 degrees, figure 2and 3.

Figures 2 and 3. Large amount of material deposited in the cart and dumped into external area.

CASE 2 - CART TO SEPARATE AND DISTRIBUTE NOTEBOOK LABELS

Description of the activity before intervention: This activity consists of distributing the labels throughout the six notebook assembly lines and is performed by a sole operator several times a day. The tasks involved in this activity are: 1) collect the empty paperboard boxes from a separate area close to the assembly line and manually bring them to the area where the sealed boxes of labels are; 2) place the labels in a box according to the requests from the production; 3) distribute the

labels in the assembly line boxes and transport them manually or using a simple cart, see figure 3; 4) wait in front of each assembly line approximately six minutes until the labels are checked and, if necessary, receive the leftover labels and relocate them into the cabinet. The cycles of this task were 1 hour long so all six assembly lines could be served, which reached an average of 10 minutes per line.

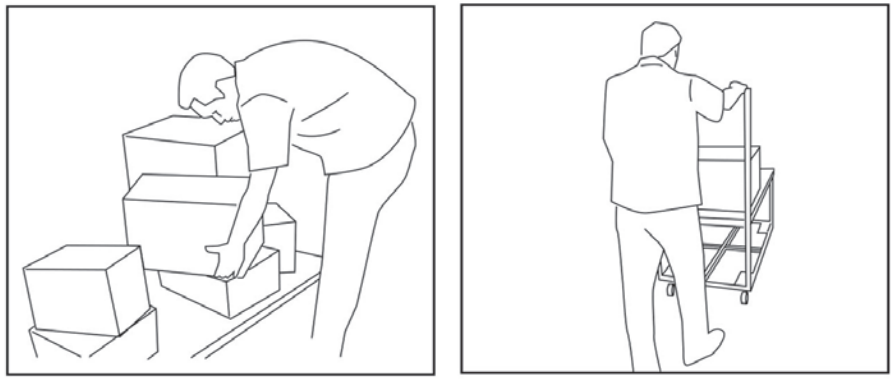

Figure 4. Lifting box to be placed onto cart and pushing the cart.

Description of the problem before intervention: During an informal 10-minute interview with the worker the following difficulties were reported: 1) difficulty to grab the boxes since they do not possess any kind of hand support, figure 4; 2) mixing and loss of material because they were not fixed in place in the box; 3) constant complaints by supervision and quality control staff due to the wrong placement of labels in the assembly line process.

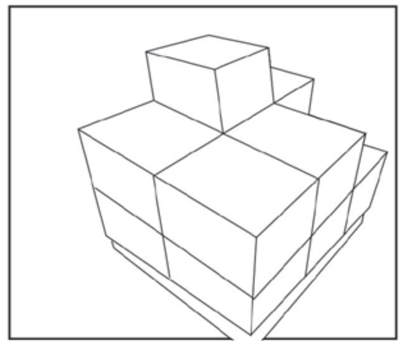

Figure 5. Boxes in which the labels were transported.

APPROACH AND RESULTS

Case 1 – GARBAGGE COLLECTION TIPPING CART

A cart (height=1m; width=0.60m, length=1.26m) with a tilt (height=0.78m; width=0.76m, length=1.11m) for collecting recyclable material was designed. The worker no longer had to position the box on his shoulders but to tilt the cart in order for the material to slide down, this action is aided by a small rake for removing the material left on the bottom of the box, figures 6 and 7.

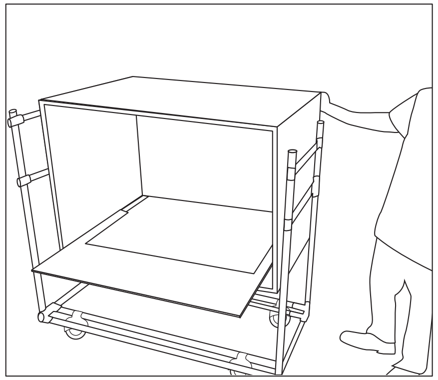

Figure 6 New tipping cart.

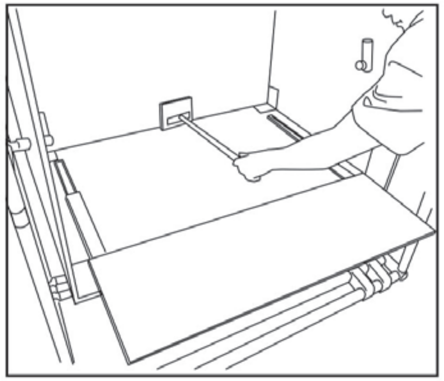

Figure 7 Auxiliary small rake.

Each cart cost U$160.00. The acceptance by the worker was satisfactory. RULA instrument returned a significant improvement outcome, see table 1.

Before Intervention	**Grand Score (right/left): 7/7** A score of seven or more indicates investigatigation and changes are required immediately
After Intervention	**Grand Score (right/left): 3/3** A score of three or four indicates further investigation is needed and changes may be required

Table 1. RULA Scores CASE 1 - For the posture adopted when collecting waste material from the box and dumping it outside.

Case 2 - CART TO SEPARATE AND DISTRIBUTE NOTEBOOK LABELS

The cart (height=1.36m; width=0.60m, length=1.34m) for the separation of labels was designed in such a way to facilitate the task for the worker as well as the storage of the labels, figure 8. The new cart allowed for: 1) more space in the storage area; 2) improvement of quality of manufactured notebooks through the elimination of the issue of mixing the materials; 3) storage to be done on the cart itself, eliminating the need for the worker to wait 6 minutes at the assembly line; 4) less physical and mental effort; 5) the decrease of the time for separating labels by 30%. The making of the cart cost U$ 285 per unit. RULA instrument returned a significant improvement outcome, see table 2.

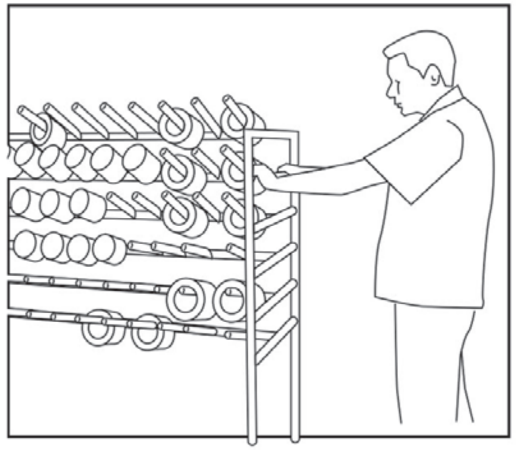

Figura 8 Label cart.

Before Intervention	**Grand Score (right/left): 5/5** A score of five or six indicates investigation and changes are required soon
After Intervention	**Grand Score (right/left): 3/3** A score of three or four indicates further investigation is needed and changes may be required

Table 2. RULA Scores Case 2 - For postures adopted when lifting the boxes and placing them onto the cart.

CONCLUSIONS

In order to remain competitive in the market, companies in the most diverse segments are always looking for cost reduction without affecting product quality or client's satisfaction. However, this can only be done effectively with the aid of a multidisciplinary team (Berk, 2010); without it, the endeavor may damage both employees' health and the company's financial health (labor disputes, absenteeism, among others) in the short and medium terms. We have initiated slight changes in the areas of support to the production process and we have observed a direct impact therein: the waste material was collected more adequately and there was a 30% gain in the separation of labels, which benefited the notebook assembly lines. We knew that good results would not come about solely through the knowledge of ergonomic principles. Literature is clear when it states that trainings should focus mainly on people's behavior (Lavender, 2006). We believe the learning of ergonomic concepts, along with the opportunity to put into practice that knowledge acquired through the development of ergonomic devices are the aspects that contributed most significantly to the positive outcomes. We must emphasize that the basis for our results stems from participatory ergonomics. Therefore, the interaction between the ergonomist, members of the ergonomic committee, those responsible for the evaluated areas and the workers express new way of working within the manufacturing areas. Not the utopian way, but the healthy one that involves constructing together, gaining together; the way that can be translated into two words: Ergonomic Team.

ACKNOWLEDGMENT

The authors want to thank the company, the workers, Mr. Carlos Pierre and his team, for supporting this study.

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A Successful Ergonomic Solution Based on Lean Manufacturing and Participatory Ergonomics

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(pp. 245-257). Springer, Cham.

ABSTRACT

This project was developed in a 1,500-employee multinational metallurgical factory. A multidisciplinary team of certified ergonomists, engineers, managers and direct employees used concepts of participatory ergonomics and Lean Manufacturing methodology to develop a workstation improvement project of large subsets, where male and female employees, simultaneously, handle large parts 96 times per shift. This study was structured in seven steps: (1) Identification of the problem; (2) Problem specification through ergonomic assessment using RULA and observational method; (3) Problem analysis, added-value classification and determination of causes; (4) Action Plan; (5) Implementation; (6) New ergonomic analysis; (7) Validation of results. The results are significant for the employees and company: the working procedure was suitable for both men and women, it eliminated unnecessary activities, it reduced costs and lead time as well as it maintained the health and safety of workers.

Keywords: Lean Manufacturing, Macroergonomics, Participatory Ergonomics, RULA Assessment, Value Adding, Non-Value Adding Activities

A Successful Ergonomic Solution Based on Lean Manufacturing and Participatory Ergonomics

INTRODUCTION

Several articles in the literature in Macroergonomics provide evidence of the success of ergonomic interventions and their positive impact on workers and businesses [1–4]. The main purpose of an ergonomic intervention is to design or adapt the workstation to the worker. The results of such interventions may be: 1. gain in worker health; 2. satisfaction of the worker; 3. optimization of the production process; 4. gains in productivity and 5. improvement in product quality [5]. There is a direct link between satisfaction of the employee at work and satisfaction in his/her personal life [6]; this fact is closely related to what we experienced in this study. However, it is necessary to point out that participatory ergonomics is an area within macroergonomic methodology.

According to Hendrick and Kleiner [7] macroergonomics is the perspective, methodology and subdiscipline of ergonomics that prioritizes the technology of human organization interface. The goal of Macroergonomics is to optimize work systems, including the participation of those involved (empowerment) in the several hierarchical levels, enabling continuous improvements within the production process. Under the practical perspective, Macroergonomics can be understood as: 1. Top down (since it requires the involvement of the company's board of directors); 2. Bottom up (for being of participatory character) and 3. middle-out (focus on the production process) [8]. Participatory ergonomics is the most commonly used approach of the Macroergonomics field because it has produced extremely satisfactory results and it has, therefore, assisted in the dissemination of the field of Ergonomics in companies [8]. The concept of participatory ergonomics is proposed by several authors in different ways, however, these definitions complement each other. Participatory ergonomics can be understood as a Macroergonomic approach that requires the involvement of workers in the implementation of new technologies in the organizational system [9]. Another definition is the involvement of people from different areas of the company in planning or re-planning their work activities; these people possess enough technical and scientific knowledge to influence the process in order to achieve the expected results [10].

This study is based on macroergonomics and participatory ergonomics as well as on the Lean Manufacturing Methodology. Because one of the main goals of Ergonomics and Lean Manufacturing is the continuous improvement, the objective of this research was to demonstrate that this can be achieved without compromising or safety of health of the workers, generating, consequently, gains for the production process. According to Koukoulaki [11], Lean Manufacturing can be conceptualized as the strategy that generates internal flexibility to meet customer requests and eliminate wastes in the production process. There are excellent articles and books that discuss the conceptualization of the Lean Manufacturing methodology. Thus, we will focus on this article to report the practical results of our intervention, based on Lean Manufacturing and participatory ergonomics in a multinational metallurgical company. It should be noted that a multidisciplinary team (including a certified ergonomist, an occupational safety engineer, a process engineer, a manufacturing manager and workers) was involved in this study of continuous improvement and it received support from the company's board of directors.

METHODS

STUDY SETTING

This study was developed in a multinational metallurgical company that employs 1,500 workers. The company has two work shifts, the first shift is from 7:00 a.m. to 4:48 p.m., and the second shift from 4:48 p.m. to 1:55 a.m. from Monday through Friday.

PARTICIPANTS

Because this was a study of continuous improvement aimed at the production process, there was no need to establish inclusion or exclusion criteria for the participants. The ergonomic intervention directly benefited a total of 8 workers, that is to say, those who perform the activity. Moreover, the intervention indirectly benefited 22 employees, totaling 30 workers involved in the production of the sets.

DEMAND FOR THE STUDY

The initial demand of the project that resulted in this study was to apply the Lean Manufacturing methodology associated with the participatory ergonomics approach in the assembly and welding of four reinforcements of a 133-kg steel plate (Fig. 1). Before the intervention, two workers, male or female, had to lower the plate simultaneously. The process of welding the reinforcements of the subset required the workers to irregularly move the pieces 96 times in the work shift (six handling per subsets - four subset per final product - four final products per shift).

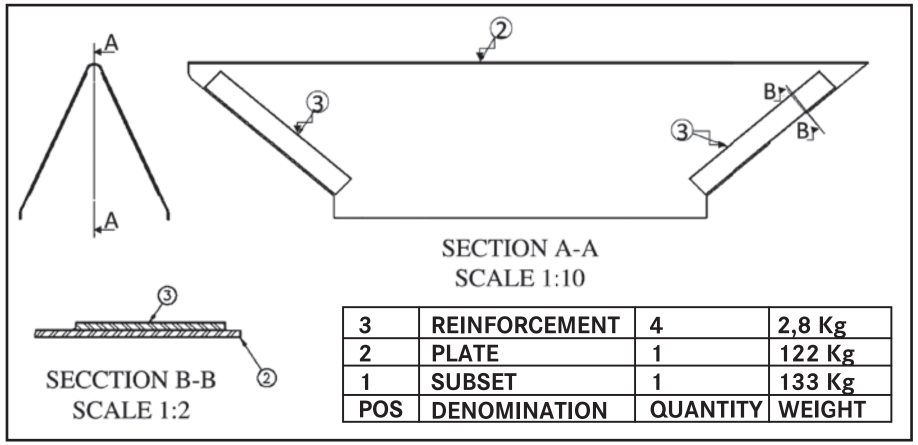

Fig. 1. Technical drawing of the subset.

PROCEDURE

This study was structured in the following seven stages: 1. Identification of the problem; 2. Problem specification through ergonomic assessment using RULA and observational method; 3. Problem analysis, added-value classification, and determination of causes; 4. Action Plan; 5. Implementation; 6. New ergonomic analysis; 7. Validation of results.

Step 1 - Identification of the Problem. The surveyed company possesses an ergonomics program coordinated by a certified Senior Ergonomist who performs ergonomic analyses of work in a preventive way. The purpose of the analyses is to identify work situations presenting room for improvement and verify the compliance of the work stations with the Brazilian regulatory norm (NR-17) of the Ministry of Labor and Employment [12]. The company holds monthly meetings in which ergonomic reports are presented to an ergonomic committee, represented by employees from different areas of the company. In one of these meetings, the presentation of an Ergonomic Analysis of Work (E.A.W.) containing images and videos of the workplace allowed the participants to identify the need for improvement in the welding of the subset reinforcements.

Step 2 - Problem Specification through Ergonomic Assessment. RULA (Rapid Upper Limb Assessment) instrument was chosen to assess the ergonomic issues involved in the performing of the welding of the subset reinforcements. RULA, which is a "screening tool that assesses biomechanical and postural loads on the whole body with particular attention to the neck, trunk and upper limbs" [13], contains values ranging from 1 to 7 which, in turn, define the action level, as shown in Table 1.

Action level	Scores	Indication
Action level 1	1 and 2	Acceptable posture
Action level 2	3 and 4	Changes are recommended
Action level 3	5 and 6	Changes are needed soon
Action level 4	7	Chandes are needed immediately

Table 1. Action levels and results for RULA.

During the welding of subset reinforcement, the manual handling of the 133-kg workpiece on the workbench was assessed. The RULA score before the ergonomic intervention was 4 (Action level 2), indicating the need for investigation and potential changes in the production process (Fig. 2).

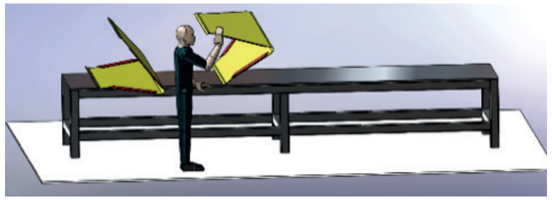

Fig. 2. Handling of the workpiece - RULA score of 4

Step 3 - Problem Analysis, Added-Value Classification and Determination of Causes. The result obtained in step 2 justified the analysis of the workstation for developing an improvement that would eliminate the need for tipping the heavy pieces. According to Pattanaik and Sharma [14], it is essential to eliminate activities that do not add value to the production process because it is the customer that generates value, not the company [15]. The literature also points out that these activities can be: 1. Overproduction: production before or beyond that which is necessary; 2. Defects: Frequent information errors, product quality issues or poor performance in the delivery; 3. Unnecessary stocks: excess storage, resulting in excessive cost and poor customer service; 4. Inadequate process: execution of a working process using wrong tools, procedures or systems, when a simpler way could be more efficient; 5. Excessive transportation: excessive movement of people, information, materials or products, resulting in loss of time and effort as well as added costs; 6. Waiting: long periods of inactivity of people, information, materials or products, resulting in poor flow, delays and longer delivery times; 7. Unnecessary movements: poor organization in the workplace, resulting in poor ergonomics, for example: excessive bending or stretching movements and frequent loss of items [16]. Thus, in order to ascertain whether there was any waste in the production process, the process engineering team and the area management applied Lean Manufacturing methodology and categorized the value of activities in the flow of pieces in AV (Added Value), NAV (No Added Value) and NAVn (No Added Value, but necessary). It was found that, among the 25 manipulations, three technical actions (OP.70, OP. 100 and OP.130) did not add value to the production process and also did not comply with ergonomic requirements. The main cause for the identified waste of the workpiece handling was that bending (OP.20) was performed before welding the reinforcements (OP.80 - OP.110). It required two workers to tip the folded workpiece onto a flat surface so the reinforcements could be welded. The last handling action (OP.130) is also carried out so the workpiece is placed into the moving position (OP.140). In Fig. 3, the operation numbers of Table 2 are illustrated.

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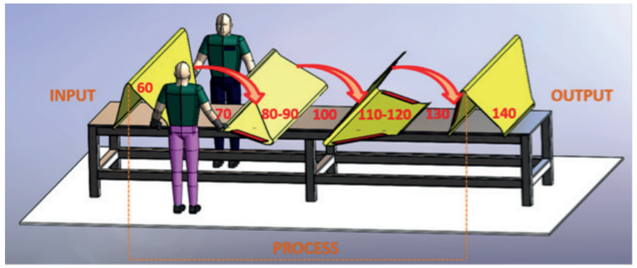

Fig. 3. Partial Flow: welding of four reinforcements before ergonomic reinforcement.

Table 2. Classification of thechnical actions before the ergonomic intervention.

Operation	Process	Items	Technical Action	Classification
Op.10	Cut	2 Part number	1 and 2	AV
Op.15	Transport	2 Pallets	3 and 4	NAVn
Op.20	Bend	1 Part number	5	AV
Op.25	Transport	1 Pallet	6	
Op.30	Transfer	2 Part number	7 and 8	NAVn
Op.35	Transport	2 Pallets	9 and 10	NAVn
Op.40	Store	2 Pallets	11 and 12	NAVn
Op.50	Transfer	2 Part number	13 and 14	NAVn
Op.55	Transport	2 Pallets	15 and 16	NAVn
Op.60	Position	1 Part	17	NAVn
Op.70	**Handle**	1 Part	18	NAV
Op.80	Position	2 Reinforcements	19	NAVn
Op.90	Weld	2 Reinforcements	20	AV
Op.100	**Handle**	1 Subset	21	NAV
Op.110	Position	2 Reinforcements	22	NAVn
Op.120	Weld	2 Reinforcements	23	AV
Op.130	**Handle**	1 Subset	24	NAV
Op.140	Position	1 Subset	25	NAVn

The number of operations in Table 2 were added to the layout for the visualization of the flow of pieces in the factory (Fig. 4).

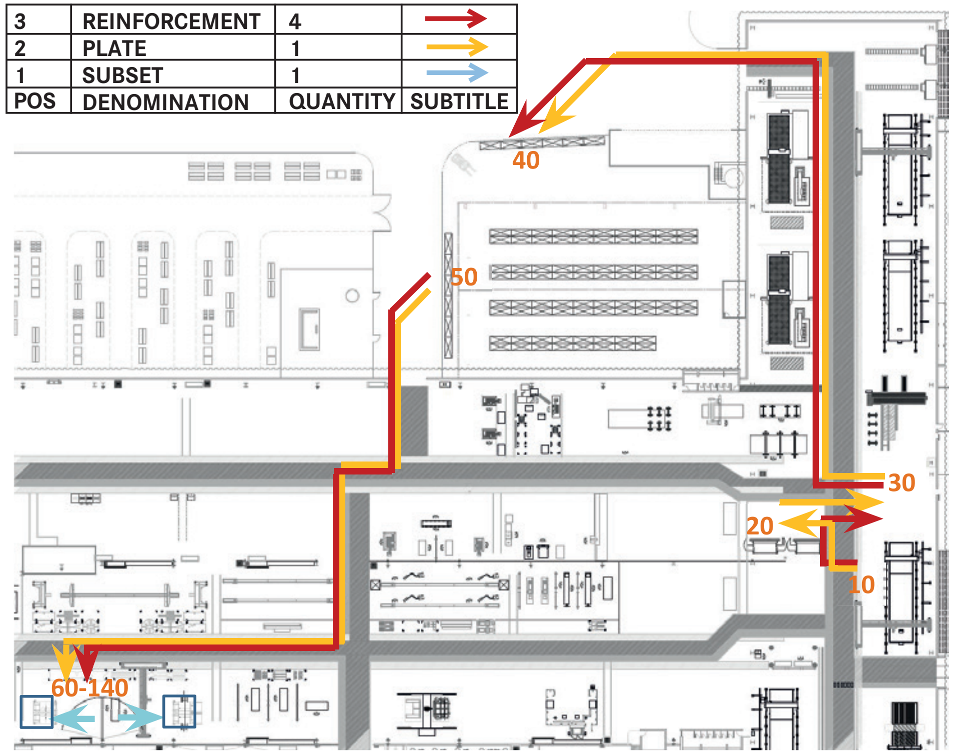

Fig. 4. Flow of workpieces in the factory layout before the ergonomic intervention.

Step 4 - Action Plan. The action plan prioritized eliminating the handling of parts. The proposed solution was to invert the welding process so it is performed before the bending and check if there would be any undesired impact, according to the following steps: (a) define the layout and the resources necessary to the welding of reinforcements; (b) provide resources; (c) define the pilot process; Once the new process was defined and validated, it was only necessary to create a safety stock of the welded subsets so that it did not impact the supply in the need to tip the workpiece was eliminated. The RULA score after the ergonomic intervention was 2, action level 1, indicating acceptable posture (Fig. 5). This result demonstrates the success of step 5.

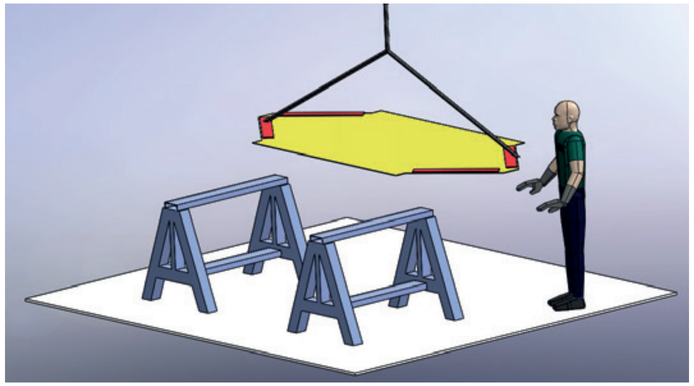

Fig. 5. Handling of the workpiece without tipping by using an electric hoist. RULA score of 2.

Step 5 - Implementation. Once the new process was defined and validated, it was only necessary to create a safety stock of the welded subsets so that it did not impact the supply in the final production line. With the stock produced in the new process, the operation involving the assembly and the welding of the reinforcements was transferred from the assembly line and started to be delivered as a subset composed of five pieces.

Step 6 - New Ergonomic Analysis.

In the welding of the reinforcements of the subset, the task of manual handling of the 133-kg pieces on the workbench was assessed and the need to tip the workpiece was eliminated. The RULA score after the ergonomic intervention was 2, action level 1, indicating acceptable posture (Fig. 5). This result demonstrates the success of step 5.

Step 7 - Validation of the Results. In addition to the ergonomic assessment before and after the ergonomic intervention, the authors administered a questionnaire on the worker perception of comfort to verify the added value of the modification of the production process for the worker. Fifteen professionals from the first shift were interviewed. The questionnaire was answered voluntarily by the participants, and the identification of the worker's name was optional, so the informant's privacy was maintained. In the questionnaire two closed questions were asked in order to identify the employee's perception of comfort when performing the activity. We also inquired about the comfort of the worker when reducing the number of technical actions required to perform the activity as a result of the ergonomic intervention. Prior to the intervention, 25 technical actions were necessary. However, a total of 16 technical actions were needed after the intervention. Furthermore, workers from the entire production chain of the assembling and welding of the reinforcements responded to the questionnaire. They were categorized into 4 groups: group 1 - those who are required to tip the metal workpiece; group 2 - logistics workers who count, sort, transfer, store and supply the workstation; group 3 - operators of bending machines and group 4 - workers who receive the welded subsets.

RESULTS AND DISCUSSION

Identification and Description of Intervention in the Production Flow

It was identified that, by adjusting the production flow in the assembly line and reducing the number of movements, the primary production processes (laser or plasma cutting and bending and welding) could be carried out in compliance with ergonomic standards and requests. This eliminated the need for transfers, dismissals as well as the hiring of new labor, since the welding process could be incorporated into activities already existing in the manufacturing area.

Classification of Technical Actions and New Production Flow After Ergonomic Intervention

After the ergonomic intervention, the new production flow led to a reduction in the number of technical actions. This is demonstrated in Table 3.

Once the handlings that did not add value were eliminated, it was evident that the flow of the workpieces, reinforcements and cut plates was reduced. This happened because after the intervention they were joined as a subset in the initial stages of the process (OP.20 - OP.50). Thus, five workpieces of two distinct items are already included when transporting, transferring or storing a subset. The new process of welding of the reinforcements is performed on the flat, unbent plate, which makes it possible for only one worker, male or female, to perform all the activity because the positioning through the input, process and output of the workpiece (Fig. 6) is carried out by an electric hoist.

Table 3. Classification of thechnical actions after the ergonomic intervention.

Operation	Process	Items	Technical Action	Classification
Op.10	Cut	2 Part number	1 and 2	AV
Op.15	Transport	2 Pallets	3 and 4	NAVn
Op.20	Position	1 Part	5	NAVn
Op.30	Position	4 Reinforcements	6	AV
Op.40	Weld	4 Reinforcements	7	NAVn
Op.50	Position	1 Subset	8	NAVn
Op.55	Transport	1 Subset	9	NAVn
Op.60	Blend	1 Part number	10	AV
Op.65	Transport	1 Pallet	11	NAVn
Op.70	Transfer	1 Part number	12	NAVn
Op.75	Transport	1 Pallet	13	NAVn
Op.80	Store	1 Pallet	14	NAVn
Op.90	Transfer	1 Part number	15	NAVn
Op.95	Transport	1 Pallet	16	NAVn

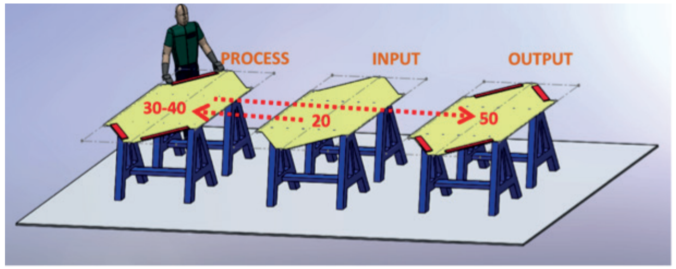

Fig. 6. Partial flow: Welding of the four reinforcements after the ergonomic intervention.

Positive Results of Applying Lean Manufacturing

In the researched company, the ergonomic intervention in conjunction with the Lean Manufacturing methodology generated positive results both for the company and for the worker regarding the organizational aspects of the workstation. These results are shown in Table 4.

Table 4. Results of the Lean Manufacturing intervention focusing on ergonomic issues.

Metrics	Before Intervention	After Intervention	Results (%)
Number of technical actions	25	16	36
Labor	2	1	50
Productivity man-hour	0,53 MH	0.35 MH	34
Cycle time	16 min	21 min	31
Recovery time	12 min	7 min	41
Daily transport	550 m	300 m	45
Physical space in operation	100 m^2	50 m^2	50
Transport/Storage	2 Part number	1 Part number	50

The 36% reduction in the tasks needed for the activity associated to the increase in the cycle time to 21 min and to the decrease of recovery time to 7 min contributed positively both to the production process and to the health of the worker.

Moreover, the physical space for the task decreased by half, freeing the layout for other operations. After the intervention, the number of employees and man-hours necessary to perform the technical actions was reduced to 1, allowing the remaining workers to perform other tasks and even develop new skills. Gains in movements were also very significant. Before the intervention, there were 4 types of parts being moved to the assembly line, afterwards, this number was reduced by 50% once the parts began to be supplied after having been assembled (Fig. 7).

Other Positive Results from the Ergonomic Intervention

Participatory ergonomics is key to the success of ergonomic interventions [17]. The following results demonstrate the positive outcomes of associating the technical knowledge of the worker with the expertise of a professional multidisciplinary team: 1. It was observed that the positioning time of the reinforcements could be reduced with the aid of a template that replaced the need to measure the position of the parts, guaranteeing standardization and quality of the assembly; 2. Prior to the ergonomic intervention, the reinforcements were welded on a fixed height table and in the new process, height adjustable trestles of 0.80 m to 1.0 m were used, allowing the worker to adjust it according to his/her height; 3. In defining the resources required to carry out the activities, only the radial arm with electric hoist was required, freeing the workbench, the

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racks and the semi-gantry crane used for positioning the pieces; 4. Storing the plates with welded reinforcements facilitates the work along the processes since the space between each plate is the width of the reinforcement, which allows the positioning during the lifting and facilitates the counting of the sets; 5. Freeing physical space on the assembly line makes it possible to combine two processes that were being carried out in different locations; 6. Elimination of transferring, storage, separation and forklift transportation of the reinforcements.

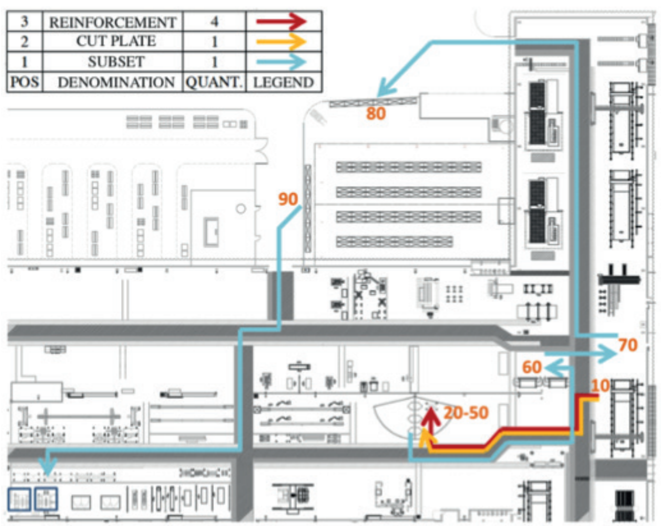

Fig. 7. Flow of workpieces in the factory layout after the ergonomic intervention.

Result of the Questionnaire on Worker Comfort Perception

People can easily tell the difference between comfort and discomfort [18] and each worker has their own perception of comfort from their experiences. Therefore, a questionnaire was necessary to determine if the ergonomic intervention resulted in comfort for the workers when performing the activity. The fifteen workers who answered the questionnaire reported that the new way of performing the activity at the workstation meets the comfort requirements, rating the ergonomic intervention as “Very good” in regard to the entire production chain.

Return on Investment in Ergonomic Intervention

A multidisciplinary team is needed to reduce costs [19]. In this study, our initial multidisciplinary approach was to optimize the performing of the activity to bring more comfort to the worker and, as a consequence, we also achieved a reduction of man-hour costs, among others shown in Table 4. Furthermore, there was no financial investment by the company, since it was not necessary to acquire new equipment or materials. All that was done in this ergonomic intervention was to reallocate resources and people, increasing the production of the final product by 33%. It should be noted that, in the assembly flow of the final product, the two workers involved in the activity produced the parts according to the demand of the next post; in terms of manufacturing, they performed the “pull production”, which in certain assembly lines shows to be very effcient. However, in this case this generated a loss in production, since the cycle time of the next stage was greater than the stage under study. This caused the workers to disperse their activities while waiting for the end of the assembly of the next stage.

CONCLUSION

From the point of view of managing the relationship between leaders and employees, this study promoted a deep analysis of how to integrate Lean Manufacturing with the expectation of people and with the constant development of practices that ensure the safety, health and quality of life of the worker. In addition, this integration resulted in higher productivity and in the elimination or reduction of waste, be it related to movements or rework. It has been shown that the lack of ergonomic analysis can be considered waste within the Lean Manufacturing philosophy. Ergonomics can be applied in organizations to increase effciency through activities that add value and through the continuous elimination of waste. This contributes to the expansion of Ergonomics in design projects to achieve goals related to the health of the worker as well as to the financial health of the company.

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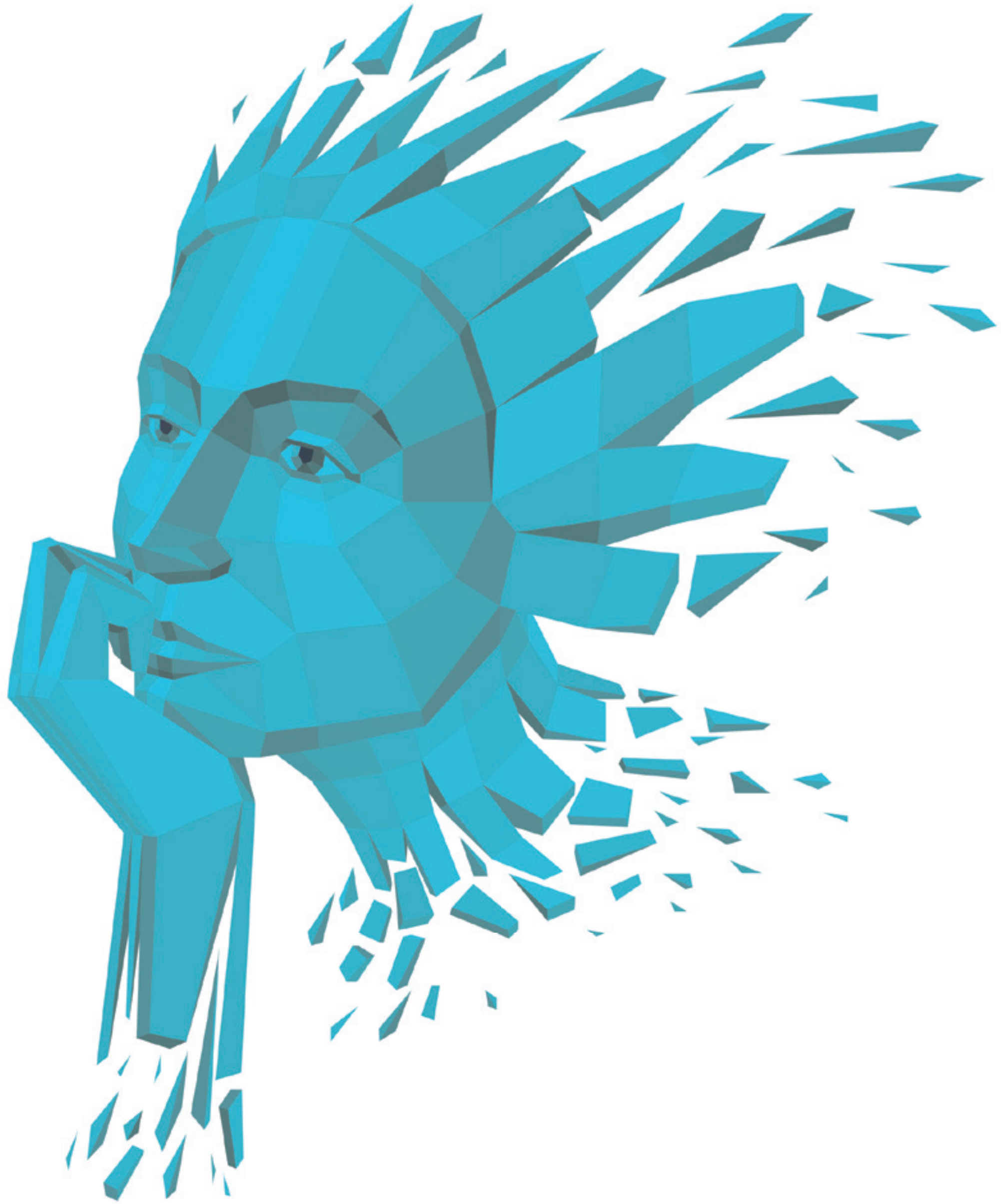

CHAPTER

6

Reflection

Reflection

As formulated in chapter three, the research question in this PhD thesis is: What challenges are faced in dealing with ergonomic risks in different industrial settings in a practical way?

As formulated in chapter three, the research question in this PhD thesis is: What challenges are faced in dealing with ergonomic risks in different industrial settings in a practical way? The cases described in this PhD thesis clearly show that there are many challenges. This work also shows that 20-year-old approaches called macroergonomics (e.g. Hendrick, 1996) and participatory ergonomics (Kuorinka & Patri, 1995) are still valid. Elements of these approaches described in the literature seem to be approved as well by the cases in this PhD thesis, which highlights the importance of elements such as 'start with smaller interventions focused on musculoskeletal problems' (Haines et al., 2002), 'involve stakeholders' (Vink et al., 2008) and 'work towards a company-wide approach' (Larson, 2014).

In chapter two, the first challenge is described. This challenge involves introducing the correct view on ergonomic risks to the company. The approach is not the same as in other health risks. The solutions will not be defined if one only looks at homogeneous exposure groups (HEGs). When determining the ergonomic risk, it is important to establish the existing ergonomic situation of the company as a basis for the development of ergonomic improvements in its site. Moreover, the ergonomic risk should not be treated the same way as other health and safety risks, because the ergonomic risk is usually directly connected to the task or activity that the worker is performing. For example, if two people are in the same room performing different activities, this could in both cases cause the same low back complaints. However, in this case, there should be two different interventions: one for the person working with a computer and another one for the worker doing repetitive lifting. Also, a different ergonomic risk must be assigned to each person in view of his or her activity. For another health and safety risk such as, for example, high humidity in the room, the intervention could be the same for both groups since they could be seen as a homogeneous exposure group. By the way, this is not a typical Brazilian issue, companies around the globe have to map ergonomic risks in order to be able to manage the working conditions; yet, in order to do this, they must possess a broader view within ergonomics. According to Kenny et al. (2012), ergonomic risks constitute a vital aspect of study and prevention for the health of the worker.

Chapter three describes a second challenge, which involves demonstrating to the company the importance of ergonomics programs and not only performing ergonomic analyses of work (EAW). These analyses alone do not contribute to creating an ergonomic culture, which improves company health and productivity on the long run. The EAWs are like the doctor's stethoscope: they will provide information on the problem (ergonomic risk), but they still require broader strategies to find the cure (prevention of the risk), which is described in the literature as well (e.g. Larson, 2014; Kuorinka & Patri, 1995).

Many ergonomists apply ergonomic practices, where they learn to identify, analyse and solve ergonomic problems, but they refrain from learning how to design ergonomics programs and, therefore, are not able to measure or manage ergonomic results within the company (Alexander and Orr, 2006). Although corporations seem to face similar problems, the contexts in which they are inserted are unique (Kilbom & Petersson, 2006) and, therefore, they require a customized ergonomics programs that takes into account the reality of each company and the way in which ergonomic actions are implemented. The success of this customization of the ergonomics programs requires an initial and crucial step by the ergonomist, which is to establish the level of ergonomic knowledge or maturity of the company as well as approaches to tackle the ergonomic issues at a macroergonomic level involving many groups within a company. Chapter three introduces the Ergonomic Maturity Conceptual Framework, a screening tool intended to assist the ergonomist in determining the degree of ergonomic maturity of the company and, therefore, facilitate the customization of the ergonomics programs.

Ergonomics programs are only possible when the company either has enough ergonomic maturity or is willing to reach it; furthermore, it is clear that the adaptation of an ergonomics program to the specific situation of a given company is a fundamental step. The ergonomics programs in this thesis was based on two different methodologies; firstly, it was based on macroergonomics, and the successful results have also been attributed to participatory ergonomics. These results are presented and discussed in chapter five. This methodological basis was employed in such a way that it allowed the researchers to develop an ergonomics program around three main pillars: 1. Normative Pillar; 2. Ergonomic Culture Pillar and 3.Management Pillar. Secondly, the establishment of the ergonomics programs also benefited from the Total Productive Maintenance methodology (TPM), which was applied in Japan in the 70's. According to Nakajima, (1989) "TPM can improve the

overall effectiveness of the facilities through an organization based on respect for human creativity and the general participation of all employees of the company."

Chapter three also touches on the content of each pillar of the ergonomics programs, such as the dissemination of the ergonomic culture within the company, the corporate culture, the politics, and the formation process of the ergonomic committee in the ergonomics programs. For instance, if an ergonomics programs has a strongly engaged multidisciplinary committee (a representative from different areas of the company, like engineers, workers from different departments, ergonomists, doctors, lawyers, designers, among others), then the chance of success for implementing ergonomic improvements is much higher. This principle of using a multidisciplinary committee is described in the literature by others (e.g Vink et al., 2008; Larson, 2014). This multidisciplinary committee, which is part of the strategies within the ergonomics programs, made it possible for the researcher to go beyond isolated actions towards the prevention of WRMDs and allowed her to foster the creation of an "ergonomic language" among the several areas of the company, mainly through the use of specific documents. Such a strategy facilitates the taking of actions and the management of the ergonomic issues and consequently contributes to the ergonomic maturity of the company. The two documents, called ETOW (Ergonomic Technical Opinion of the Work) and ETOP (Ergonomic Technical Opinion of the Process) could contribute to the success. The ETOW aims at the individual ergonomic assessment of the worker in his or her work environment. The ETOP intends to ergonomically assess the production process. These documents are a means of communication between the ergonomist and other areas in the company such as labour medicine, labour safety, production engineering and legal area.

According to Larson (2012), an ergonomics program must go beyond protecting the company's assets by including within its scope elements such as: safety and health of the workers, quality, productivity and the company's reputation. Moreover, according to Dul and Neumann (2009), it is important to build a strategy for the "ergonomic language" to be a common language throughout the company. Unfortunately, despite the success of ergonomics programs, ergonomics is not always part of the company's business strategy and, consequently, is most commonly used when there is a need to conform to certain regulations (Dul and Neumann, 2009). The uniqueness in Brazil is that there is a special regulatory standard for ergonomics (NR-17), which says that companies must invest in ergonomic issues, otherwise they run the risk of being prosecuted by the Ministry of Labour and Employment. This is a federal Brazilian norm and is valid within all Brazilian states, with no exception.

The third challenge is discussed in chapter four, which describes a situation in which understanding the background of the human body movement in the activity at work is essential. Sometimes the way of moving may be the result of the physical characteristics of the workstation, but it may also stem from the specific way the employee decides to perform his or her work. This could be, for instance, sitting in an awkward posture or handling a load in an unhealthy way. Therefore, when analysing an awkward posture, the ergonomist should not adapt the work station immediately; first, he or she must observe more than one employee performing the same task in order to assess whether the awkward posture is caused by the environment or by the behaviour or movement carried out by that specific employee, which is described in the literature as well (e.g. Jong & Vink, 2002). Ways of improving this situation may include encouraging the employees to ponder if that posture is really necessary and demonstrating another way of doing the task or showing examples of other employees doing it. Investigating the body movements at work is important because it allows the ergonomist not to incorrectly assign ergonomic risk to the adoption of wrong postures assumed by the worker him or herself and not because the work itself requires it. This situation has also drawn the attention of a French study (Lémonie & Chassaing, 2014), which conceptualizes it as work gesture.

Chapter five shows that macroergonomics programs can lead to successful improvements in different Brazilian companies and have a positive effect on the health of the workers by reducing musculoskeletal disorders and, most of the time, increasing productivity. In the future vision on ergonomics of Dul and Neumann (2009), they state that this combination between productivity and health is of vital importance. According to Guimarães & Fogliatto (2000), macroergonomics can be understood as: 1. top-down, since it requires the involvement of the company's board of directors; 2. bottom-up, because it is of a participatory character, and 3.middle-out, since is focuses on the production process. The implementation of macroergonomics programs has taken place in various companies in the world. In this PhD thesis, the experience ranges from metal industries (train manufacturer), greenhouses, and electrical device assembly companies to a hydro electrical company. So, the principle is not sector specific. It even is not country specific as it has been successfully applied both in developed and developing countries (e.g. Kogi, 1995). Support from the upper management of the companies described in the literature (e.g. Koningsveld et al., 2005) is fundamental for the successful results showed in this thesis and critical to attain in the model.

As it has been mentioned, the research question of this thesis involves the challenges faced when dealing with ergonomic risks in different industrial

settings in a practical way. As it has been demonstrated, many of these challenges are comparable to issues faced by companies worldwide. However, there are two elements in the implementation of ergonomics programs that are unique to the Brazilian context, one is the NR-17 – enforced by the Public Ministry of Labour and Employment – and the other is the fact that more physical demanding work is done in Brazil than in industrially developed countries. Moreover, the greatest challenges faced in these projects were not included in the definition of the specific problems at the work stations, instead, the continuation and upscaling were the most challenging actions, and they emerged a while after the ergonomic projects had started.

There are two of these special challenges that are worth mentioning. The first one involves the difficulties in establishing an efficient ergonomics programs in a company whose purchasing department has specific policies and is focused on price reduction and, consequently, the scope of the program without considering the implications of this action to all stakeholders and actively involving them. It is important to mention that using the cheapest, minimal ergonomics programs may not provide the best impact in terms of productivity or quality improvement (Koningsveld et al., 2005). The second special challenge is related to the bidding practices that are rather common in some Brazilian companies. In Brazil, the contracting companies ask for annual bids for ergonomic services in search for lower prices. This practice takes place even when the company already has a team of ergonomic consultants. This attitude can be a factor for preventing the company to achieve ergonomic maturity because the ergonomic projects that are running or requiring continuation are interrupted and restarted by another team.

As a result, the background knowledge and positioning in the company is lost and a new plan must be made, causing the customized strategies developed by the consultancy to be lost, forcing the newly hired consultancy firm to discover them again. The ergonomic maturity could be lost, as the new contractor will have to restart the ergonomic work using its own methodology and strategies, which may differ from the one before; this also causes employees to lose faith in the process and momentum. An additional complicating factor is that there is not a standard procedure or a standard answer to the problem, especially when there is a change in management during the process and a restart is needed.

All of these problems may disrupt the period that is necessary for a company to reach ergonomic maturity. There are other studies showing that an efficient ergonomic intervention will take much more than a year, Molen (2005) improved bricklaying work and also showed that the first effects of ergonomic maturity are shown only after 1 year (Molen, 2005) and continuation is needed to really implement the improvements. Looze et al. (2010) describes benefits of an ergonomics programs in an emergency light producing firm over a period of 5 years.

This process is also iterative, as well as participatory. Getting stakeholders involved takes time.

In chapter one, it is mentioned that, according to Falzon (2014), the ergonomic work can no longer be limited to just adapting the physical environment to the worker. The studies presented in this PhD thesis clearly show that a more holistic view is required. The various factors (biomechanical, organizational, psychophysical, individual) in the working conditions that need to be arranged should be considered simultaneously (Occhipinti & Colombini, 2016). In chapter five, in the example of the greenhouse, both the mental workload – the counting of the elements – and the physical workload were considered in the task. The new cart eliminated the counting task (reduction of mental workload) and reduced the physical workload, revealing the benefits of a holistic approach as well as stressing the importance of the combination of health and productivity, which is a recurrent issue in many chapters in this PhD thesis.

After performing these interventions some elements were rather successful, but they could have been even more so. It is not based on the hard data of this research, but the training seemed to be very helpful before implementing the ergonomic adaptations and interventions. If it were possible to start the studies again, it would probably be beneficial to have more ergonomic training for the workers as well as implement a yearly follow-up program that would track the ergonomic maturity of the company and all its implications. The effect of training before the real implementation has been described in the literature. For instance, Robertson et al. (2009) undertook a large-scale field intervention study to examine the effects of ergonomics training coupled with adjustable work stations. The trained workers exhibited higher levels of behavioural transformation and had lower musculoskeletal risk than the control group. However, having experienced the effect yourself makes you really aware of the effect.

A limitation of this PhD thesis is that it was not always possible to gather quantitative data as companies did not allow the publication of these data. The lack of some quantitative data does not impact the results the thesis because, as mentioned before, the purpose of this work is to highlight the importance of ergonomic management in different industrial settings and bring practical experiences of the qualitative issues of how to deal with those situations. The surveyed companies authorised the publication of the work as long as their identity and quantitative information were not included in it. They made this request because they want to avoid exposing themselves to potential labour liabilities. In Brazil, we have a regulatory norm from the ministry of employment (NR-17) that, on one hand aids in the development of ergonomics in the country but, on the other, provides arguments for employees to sue their employers. Thus, most companies in Brazil are afraid of disclosing information based on cases that show work conditions before and after ergonomic improvements. Another possible limitation of this thesis is the fact that the model of the ergonomics program used is just one approach. Ideally, various approaches are developed and compared with each other. The latter problem has been described before (e.g. Koningsveld et al., 2005; Larson, 2014). The current approach seems to work and had positive effects because elements of the approach such as starting with small interventions on problems that are experienced by the company and its employees (Haines et al., 2002), involving the correct stakeholders (Vink et al., 2008), working towards a company-wide approach and taking more than a year (Molen, 2005) are of significant importance as described in the literature. Therefore, the qualitative research explained here can contribute to the continuity of future studies on this subject.

For the future it would be interesting to have case-control studies on these approaches. In the approaches variation of steps and ways of intervening there should be a study of the most effective and efficient ways. On the other hand, the consultants or ergonomists have their own style, which makes generalisation sometimes difficult. In macroergonomics, there are no good case-control studies. Usually the studies are case descriptions comparing the old with the new situation (e.g. Koningsveld et al., 2005; Looze et al., 2001). In participatory ergonomics, there are some case-control studies, like the studies of Molen (2005) and Chau et al. (2004), who applied the participatory approach in the construction industry and used the case-control set up. This means it is possible, but not easy.

In conclusion, this reflection showed 1. that the ergonomist is also the designer of invisible things, like studying who should be involved in ergonomic issues and training different groups in the company; 2. that there is not much literature about designing ergonomics program focusing on the assessment of ergonomic maturity in companies, and these specific programs are essential for the establishment of an ergonomic culture, which will provide much improvement to the work environment leading to better productivity and health; 3. that suitable ergonomic solutions can be implemented without the need for large financial investments, but adopting participatory ergonomics and management buy-in is crucial for the success of these solutions; 4. that dealing with ergonomic risks in different industrial settings requires experience of the ergonomist, who, in turn, must take into account the ergonomic maturity of the company.

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SYMONE ANTUNES MIGUEZ was born on February 19, 1967, in Belo Horizonte, in the state of Minas Gerais, Brazil. Her passion for Ergonomics arouse during her undergrad studies in Physiotherapy at Pontifícia Universidade Católica de Campinas (PUCCAMP), Brazil, where, in 1992, she graduated and wrote her research final paper entitled “Prevention of Musculoskeletal Alterations”. In this work, Symone researched the activity performed by mailmen working at Brazil Post (Correios) and suggested ergonomic improvements to eliminate work-related musculoskeletal discomforts. In 1995, she deepened her research on the pathologies and rehabilitations of upper limbs, having obtained the title of Specialist in Hand Therapy by the University of São Paulo (USP). In 2005, she received the title of Master in Nursing and Labour, within the research line of Worker’s Health and Ergonomics by the Faculty of Medical Sciences in the department of Nursing at the State University of Campinas (UNICAMP). Her academic interests and willingness to meet new people and cultures led her to Delft University of Technology, in the Netherlands, where, in 2018, she was awarded the title of PhD in Design and Engineering, at the Department of Industrial Design, Applied Ergonomics & Design (TU Delft). Besides the academic activities, Symone holds the following credentials: Senior Professional Ergonomist certified by the Brazilian Ergonomics Association (ABERGO) since 2007; Board Member/referee of Work Journal: A Journal of Prevention, Assessment & Rehabilitation; rapporteur of the Special Committee of Studies (CEE-136) of ISOs 11226, 12295, 11228-1 and 11228-2 at the Brazilian Association of Technical Standards (ABNT); and technical expert in Ergonomics of Salto Labour Court, belonging to the 15th Regional Labor Court of Campinas, São Paulo, Brazil. Symone shares her knowledge by giving lectures as a visiting professor at several Brazilian universities as well as a speaker in national and international congresses, being part of scientific committees and acting as co-chair in some of these events. Regarding her professional activities, Symone has a vast, 25-year experience within the field of Ergonomics. It should be noted that, for the past 9 years, she has been the director of Ergosys Consulting in Ergonomics, company which was founded by her and provides services to national and multinational companies in several segments.

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