International Journal of Industrial Ergonomics 49 (2015) 97–107

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Participatory ergonomics intervention for improving human and production outcomes of a Brazilian furniture company

Lia Buarque de Macedo Guimarães*, Michel Jose Anzanello, Jose Luis Duarte Ribeiro, Tarcisio Abreu Saurin

Graduate Program in Industrial Engineering, Federal University of Rio Grande do Sul (UFRGS), Av. Osvaldo Aranha, 99, 5° andar, 90035-190 Porto Alegre, RS, Brazil

ARTICLE INFO

Article history:
Received 8 August 2013
Received in revised form
24 January 2015
Accepted 2 February 2015
Available online 20 February 2015

Keywords:
Participatory ergonomics
Furniture manufacturer
Functional work design
Cellular work design

ABSTRACT

This article presents a participatory intervention in a furniture manufacturing company in Southern Brazil aiming to improve both ergonomic and production outcomes. The existing Tayloristic model was replaced by a cellular teamwork model. Work enlargement and enrichment, and the improvements in workstation design and process flow increased worker satisfaction and reduced postural risk, fatigue, body pain and production waste. Workload was reduced by 42% and productivity increased by 46% (25% being attributable to unnecessary load handling, waiting and transportation, and 21% attributable directly to manufacturing times). Workers' participation in the stages of problems identification, design and evaluation of solutions played a major role in these outcomes.

Relevance to industry: This study indicates that it is possible to balance ergonomics and production demands, and that it is necessary to make it clear to management. The integration of macroergonomics and production management principles increases both worker well-being and productivity levels, thus leading to a more sustainable system.

1. Introduction

Furniture manufacturing is an important industry in many countries (Mirka et al., 2002a; Gauthier et al., 2012; Ratnasingam et al., 2012). In Brazil, 18.7 thousand furniture companies employed 328.6 thousand people in 2013, which is the equivalent to 3.3% of the employments in the industrial sector (IEMI, 2014). However, workers in furniture manufacturing are often exposed to hazards such as dust (Goldsmith and Shy, 1988; Vinzents, 1988; Pisaniello et al., 1991, 1992; Scheeper et al., 1995; Demers et al., 1997; Holcroft and Punnett, 2009; Ratnasingam et al., 2010, 2011), chemicals (Goldsmith and Shy, 1988; Voog and Jansson, 1992; Vinzents and Laursen, 1993; Estill and Spencer, 1996; Holcroft and Punnett, 2009; Ratnasingam et al., 2010, 2011), noise (Vinzents and Laursen, 1993; Holcroft and Punnett, 2009; Ratnasingam et al., 2010, 2011), tool vibration (Gauthier et al., 2012), hazardous machinery, vehicle traffic, fires and explosions (Holcroft and Punnett, 2009).

Work in the furniture industry has been described as heavy and repetitive, involving frequent lifting, pushing and pulling of heavy loads, and the adoption of awkward static postures, like bending and twisting (Holcroft and Punnett, 2009; Mirka et al., 2002a,b; Ratnasingam et al., 2010, 2011). Such factors offer occupational risk for work-related musculoskeletal disorders (WMSD) (Christensen et al., 1995; Mirka et al., 2002a,b) and injuries (Aaltonen, 1996).

Workstation improvements, such as sit-stand seating (Urlings et al., 1990), height-adjustable tables, lift-assisting devices (Mirka et al., 2002a) and better hand tools (Mirka et al., 2002b) have been proposed in order to mitigate WMSD and accidents in furniture manufacturing. However, it is known that improvement in work design by job enlargement and enrichment plays a major role in WMSD risk prevention (Carayon et al., 1999; Rivilis et al., 2006, 2008) and has proved to reduce the high prevalence of WMSD in the furniture industry (Christensen et al., 1995). For example, Hunter (2008) enlarged the work using a cellular design in a furniture assembly unit: cell workers walked from one workstation to another on rubber mats to reduce fatigue, and moved hardware assembly fixtures along roller conveyors. Such improvements reduced musculoskeletal disorders risk and increased productivity

* Corresponding author. Tel.: +55 51 3308 3948; fax: +55 51 3308 4007.
E-mail addresses: liabmg@gmail.com, lia@producao.ufrgs.br (L.B.M. Guimarães).

http://dx.doi.org/10.1016/j.ergon.2015.02.002
0169-8141/

by 11.2% (Hunter, 2008). Cell manufacturing is indeed widely known as a strategy for improving production management by shortening lead times, improving product quality, and increasing flexibility (Sheridan, 1990).

Empirical studies rarely explicitly link practices and principles from ergonomics and production management regardless of the synergistic relationship between both disciplines. This is an important drawback as positive impacts of work organization interventions are likely to arise from ergonomics and production-oriented actions rather than isolated initiatives.

The goal of this study was to re-design a production system to address both human and production demands according to macroergonomics, i.e., relying on participatory ergonomics and focusing on the process rather than the workstation. The study is aligned with a trend in ergonomics that argues for the balance between production demands and ergonomics to achieve a sustainable production system (Hendrick, 1997; Dul and Neumann, 2009; Thun et al., 2011; Westgaard and Winkel, 2011). This study also aims to contribute to the literature on participatory ergonomics (Noro and Imada, 1991), which seldom focus on the social relations in workplaces (Dixon and Theberge, 2011) since the focus is mainly on the importance of worker participation on the appraisal stage for hazard identification (Wilson et al., 2005; Cann et al., 2008) and its effects on health outcomes (Brown, 1993; Kuorinka and Patry, 1995; Halpern and Dawson, 1997; Haims and Carayon, 1998; Moore and Garg, 1998; Hignett et al., 2005; Laing et al., 2005; Haukka et al., 2008; Rivilis et al., 2006, 2008) although considering productivity is also relevant (Brown, 1993; Nagamachi, 1996; Looze et al., 2005; Rosecrance et al., 2005; Vink et al., 2008). This study details how workers and managerial staff endured the appraisal, proposal of solutions and testing stages aimed at improving work quality and productivity; it also presents the impacts of the intervention on both social and organizational climate.

The study resulted from a partnership between the University in charge of this study and a large Brazilian furniture company, which needed a model that would balance production and ergonomic issues in the new facilities to accommodate for the expansion of the sofas manufacturing sector.

2. Method

2.1. Overview of the company and project team composition

The company, established in 1970 in the State of Rio Grande do Sul in Brazil, employs more than 4000 workers in the furniture, mattress and chemical sectors. Around 90% of the furniture is manufactured for the internal market. Sofa manufacturing requires 290 workers (166 men and 124 women) grouped in 16 sectors. Only four out of six sectors related to assembly/transformation (wooden frame assembly, straps placement, foam gluing, and upholstery), encompassing 81 workers, were supposed to occupy the new facilities. Therefore only those sectors were focused on this study. The project team was composed of four ergonomists (two engineers, two physiotherapists), three industrial engineers from the University, two managers and the workers from the mentioned sectors.

2.2. Ergonomic evaluation

Ergonomic evaluation followed the participatory Macroergonomic Work Analysis (MA) method (Guimarães, 1999) assuming that worker participation in an ergonomic intervention assures better acceptance of new ideas (Hendrick, 1990; Brown, 1995; Nagamachi, 1995, 1996). In the MA there are discussion meetings (named gates) held between each stage of the ergonomic intervention (appraisal, diagnosis, proposal of solutions, prototyping, and validation), which engage workers and keeps them aware of project developments. A total of 77 workers from four sectors of the company joined the appraisal stage, and 11 volunteer workers from these sectors took part in the prototyping, testing and validation stages. Diagnosis was mainly developed by the University's experts, while proposals for solutions, testing and validation stages involved these experts along with 2 managers and the 11 volunteer workers.

The appraisal stage comprises the identification of worker demands and experts' observations, and follows the three first steps of the Macroergonomic Design (MD) method (Guimarães and Fogliatto, 2000):

1) interviews for gathering information on user ergonomic demands or ergonomic demand items (EDIs);
2) identification of an importance score for the EDIs based on how often they are mentioned by respondents in the interview, and on the order in which items are mentioned. Items are scored, for each respondent, according to the order of their mentioning (i.e. first mentioned EDI scores 1, second scores 2, third scores 3, and so on). The item importance weight is then given by its inverse order, therefore first mentioned items received higher scores: $1/1 = 1.00$; $1/2 = 0.50$, $1/3 = 0.33$ etc. Items from all interviews are reviewed and grouped to avoid replication due to how respondents may refer to the same EDI by different names. The final importance score of each EDI is obtained summing up the scores from all respondents;
3) incorporation of experts' opinion for the inclusion of EDIs not identified by workers but deemed important by the experts.

Steps 1 and 2 rely on semi-structured interviews with approximately 30% of the workforce, and stage 3 is performed by the ergonomists through observation and analysis. These steps provide qualitative data to design a questionnaire to be answered by 100% of the workforce through the marking of a 15 cm continuous scale (Stone et al., 1974) with two anchors (i.e., not satisfied/very satisfied or none/a lot). Therefore, quantitatively, the value of an EDI varies from 0 to 15 and the weight of each EDI is generated by the arithmetic average of the results from all respondents.

The appraisal gate has three major goals: 1) confirm the most important EDIs to be fully analyzed in the diagnostic stage and to be considered in the proposal of solutions; 2) plan for the prototyping stage by defining how and when prototyping will take place; and 3) call for volunteers for the prototyping stage. The results from the questionnaire and ergonomist observations lead to the diagnosis and subsequent proposal of solutions, testing and validation stages.

Two ergonomists interviewed 26 volunteer workers (32% of the population working in the four sectors) individually or in groups depending on worker preference and practical constraints in the appraisal stage. Interviews lasted 10–40 min and were based on generic questions such as: what do you think about your work? What is good? What could be better? What suggestions for improvement do you have? Interviews were tape recorded for further analysis with worker permission. EDIs mentioned by all groups in addition to ergonomist questions of interest resulted in four different questionnaires to accommodate particularities of the four sectors. Questionnaires encompassed a total of 47 questions grouped in six constructs: physical environment (four questions), work content (13 questions); pain/discomfort (eight questions); workstation (eight questions), work design (eight questions); and company (six questions). Workers received the questionnaires in the morning and handed them out on the afternoon of the same day. 95% of the population of the four sectors (77 workers) answered the questionnaires. Questions (EDIs) from the six