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A System Approach on Safety Management and Ergonomics

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Abstract : Researchers explored how small and medium-sized businesses (SMEs) can benefit from a system-based strategy that combined ergonomics with safety management to make workplaces safer, healthier, and more productive. Work systems can be better adapted to human capabilities through ergonomics, and risks can be more effectively managed through safety management. Results from a cross-sectional study of 321 employees from SMEs revealed significant associations between ergonomic risk factors and musculoskeletal diseases (MSDs). The study used standardized questionnaires and the Rapid Upper Limb Assessment (RULA) to draw these conclusions. Press operators had the greatest prevalence of MSD symptoms, which affected around 67.6% of workers. These symptoms mostly manifested in the lower back, shoulders, and wrists. Productivity increased by 4.81%, absenteeism decreased by 8.77%, and MSDs decreased by 8.09% once the system approach was put into practice. Significant correlations between lower accident rates, supervision, and safety instruction were found. To assess safety management procedures, a validated model was created. According to the study's findings, combining safety management and ergonomics from a systems approach improves occupational health and fosters long-term industrial performance.

Index Terms - Ergonomics, Safety Management, System Approach, Musculoskeletal Disorders, Occupational Health, SMEs, Workplace Safety, Productivity, Safety Culture.

1. INTRODUCTION

Ergonomics comes from Greek words “ergo” (works) and “norms”, (natural laws). In practice, it consists of scientific principles (laws) applied in minimizing the physical stress associated with the workplace. Ergonomics is an approach in which human can produce their work in harmony with the machine to the betterment of work, quality, quantity and the improvement of the physical and behavioral environment. The application of ergonomics within an organization can result in the improvisation of working techniques, working conditions, environment, reduced error, stress, and fatigue. Ergonomics increases efficiency by designing or modifying the job by eliminating non value-added process and hazards that increase the risk of injury. By reducing disabilities, absenteeism, physical and mental strain, increasing work satisfaction and productivity, ergonomics contributes to a better quality of life. Thus, the ergonomics field is committed to systems orientation in which nothing exists in isolation and each element has the potential to impact another [Hoffmeister *et al*., 2015, Sanders, 1993]. Tayyari and Smith [1997], “ergonomics is an applied science that co-ordinates the design of devices, systems and physical working conditions with the capacities and requirements of the workers”. According to the International Ergonomics Association (IEA, 2000), “ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance” [Wilson, 2000]. There are different definitions of ergonomics; they have following aspects which are common; uses scientific data about the human; the inter-disciplinary nature; the design of machines, equipment, information systems; fitting machines, environments and work to the human, and not the opposite; safety, comfort and well-being [Coelho, 2011].

Ergonomics is interdisciplinary and there is an important problem of how it should best be fitted into an existing organization. It overlaps into many other fields because it is concerned with people and people are the basic and all-pervading resource of every organization. Traditionally, the domains of specialization within human factor ergonomics (HFE) classified as physical, cognitive, and organizational ergonomics. Physical ergonomics is concerned primarily with human anatomical, anthropometric,

physiological, and biomechanical characteristics as they relate to physical activity. Cognitive ergonomics focuses on mental processes such as perception, memory, information processing, reasoning as they affect interactions among humans and other elements of a system.

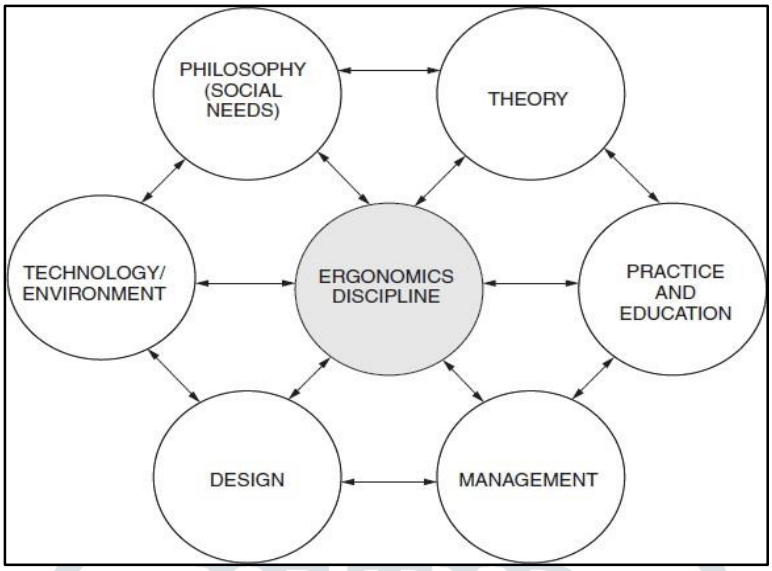

Figure 1 General fields of ergonomics (Karwowski, 2005)

Organizational ergonomics (also known as macro ergonomics) is concerned with the optimization of sociotechnical systems, including their organizational structures, policies, and processes [Karwowski, 2006]. Safety is defined as a condition where human is free from injury. The systematic and planned activity driven by the management for controlling health and safety hazards is termed as safety management. Safety management system is a proactive and systematic approach to identify, evaluate, prevent and control of hazards that could occur as a result of failures in process, procedures, or equipment. The aim of safety management is to identify the processes, that lead to near miss and accidents [Booth and Lee, 1995]. Increasing industrial accidents, loss of life and property, public scrutiny, statutory requirements, aging facilities and intense industrial processes, all contribute to a growing need for safety management program to ensure safety and risk management. With globalization and opening up of our economy, Indian organizations from various sectors have started to take initiatives to get the management system certifications such as ISO 9001, OHSAS 18001 and ISRS certifications to compete in the international market.

In ergonomics, use of system approach is well established. Ergonomics with system approach is found in various applications like aviation, rail transport, and nuclear power**.** Chapanis (1996) defines a system as "an interacting combination, at any level of complexity, of people, materials, tools, machines, software, facilities and procedures designed to work together for some common purpose". The systems approach uses a number of structured problem-solving and decision-making tools. These tools are easy to use, and they help provoke questioning and creative thinking.

2. Literature Review

The ergonomic approach in the design of work system encourages workers and management at macro and micro level resulting in increased productivity, health and significant cost reduction and contributes to different company strategies to support the objectives of business functions and of the organization as a whole [Dul and Neumann, 2009]. Most of the ergonomics studies have been conducted on modification in the work environment so that work environments will be comfortable for humans. While working the workers are exposed to various activities due to which they are subjected to biomechanical exposures, psychosocial stresses, and individual risk factors. Low perceived support from management, social support, education, and time pressure to do the job may also result in psychosocial stresses [Hermawati *et al*., 2014]. To reduce the workload and ergonomics risk factors, job rotation and cross training of the workers was found to be a significant approach for production systems or assembly work (Mossa *et al*., 2016). It was observed that each of workplace design factors have the significant effect on productivity, however, the magnitude of their effect varies [Resnick and Zanotti , 1997]. For low level of safety, workplace health, quality, and overall productivity ergonomics deficiencies are found to be the root cause, especially for manufacturing industries. In developed countries, use and applications

of ergonomics have gained significant momentum, whereas its awareness remains low in developing countries. Ergonomics technology, if properly applied, can eliminate or reduce occupational health and safety (OHS) problems at the workplace and improve performance [Shikdar and Sawaqed, 2004]. Musculoskeletal disorders (MSDs) are considered to be the serious problem for the manufacturing industries due to their poor working conditions and the absence of an effective work injury prevention programs. MSDs are the major cause of pain, disability, absenteeism, reduced productivity, and heavy financial costs among workers worldwide. As per occupational safety and health administration (OSHA), regional impairments of muscles, tendons, ligaments, nerves, spinal discs, blood vessels, and joints is known as Musculoskeletal disorders. There is no unique cause related to these disorders, however many studies have shown that physical risk factors, psychological factors, environmental factors, and individual factors; (a) physical factors - e.g., awkward postures, repetition (b) psychosocial factors - e.g., work pace, monotony (c) environmental factors - e.g., noise, light intensity, and ventilation (d) individual factors - e.g., age, gender are the contributing factors for the development of MSDs. [Widanarko et al., 2014; Isabel and Pamela, 2012; Punnett, and Wegman, 2004; Heneweer *et al*.,2011; Lötters *et al*., 2003; Bernard, and Putz-Anderson, 1997]. Safety management is one of the management activities. Different organizations have different management practices and ways to control health and safety hazards. Safety climate/ culture is considered to be an effective tool for measuring workplace safety in a manufacturing environment (Baek, *et al*., 2008). Safety climate key dimensions like management contribution, safety training, worker's involvement, safety participation, and organization support and so on; however, they vary from industry to industry and there is no particular safety survey which is considered the most effective for all types of industry (Zohar, 2002; Lee and Harrison, 2000; Hayes *et al*., 1998). Zohar (1980) based upon Israeli manufacturing sample developed 40 item safety climate questionnaire. Expletory factor analysis (EFA) converted these 40 items into 8 dimensions: management attitude towards safety, safety training, safe conduct on promotion, level of risk at the workplace, effects of work pace on safety, status of safety officer, effects of safe conduct on social status and status of safety committee. Cox and Cheyne (2000) developed a safety assessment questionnaire for offshore environment. This questionnaire consists of 47 items divided into 7 groups; management commitment, safety communication, priority of safety, safety rules and procedures, supportive environment, personal priorities and need for safety, personal appreciation of risk and work environment. Ghahramani and Khalkhali (2015) conducted a study in six manufacturing industries in Iran and developed a questionnaire for safety climate. The EFA resulted 45 items in seven safety climate dimension; safety commitment and communication, safety involvement and training, positive safety practices, safety competency, safety procedures, accountability and responsibility, and supportive environment. The available literature is majorly focused to either specific industries or processes. Ergonomic approach as well as safety culture parameters vary from industry to industry and studied independently. Ergonomic approach creates opportunities for the analysis and design of any situation in which human act, as its primary function to strive for maximum efficiency. Safety culture/climate considers psychological, behavioural and organizational factors which fit with an ergonomics approach to system analysis. Most of the studies conducted in context of ergonomics in SMEs of Industrially developing countries (IDC) are related to work-posture and design of work stations and very few on health and safety to improve the productivity. There is less research evidence from developing countries like India where safety management has gained attention recently.

3. SCOPE FOR RESEARCH

The scope of research is given below;

- To study the impact of application of ergonomics and safety management practices in SMEs for improving working condition, arrangement of tools and equipment, material handling problems, and reduction in MSDs.
- To develop the safety culture model and correlate different parameters like management contribution, safety training, safety rules and regulation, safety motivation.
- To find the use of system approach to reduce MSDs, accident and near-miss rate, absenteeism and improve safety, and productivity.

4. OBJECTIVES

- To assess the ergonomics conditions and safety management practices in SMEs
- To determine the correlation and impact of various ergonomic risk factors (ERF) with the MSDs development
- To use the direct methods for posture analysis and 2D biomechanical predictions

- To classify various jobs based upon energy expenditure
- To find the correlation between accident rates and safety management factors
- To develop the model to evaluate the status of safety management practices in SMEs
- To use the system approach and study its compliance towards ergonomic and safety management criteria.

5. METHODS AND MATERIALS

This cross-sectional study was conducted to investigate the knowledge and application of ergonomics and safety management practices in SMEs. Questionnaire and observational methods are used by ergonomists in the context of health and safety of the workers. These methods are easier to use, flexible, and less costly. So, questionnaire method was used for conducting a survey in this study. The questionnaire was divided into four different parts; part (I) demographic characteristics, part (II) consists of ergonomics assessment, and part (III) consists of safety management questionnaires. The response to ergonomics and safety management practices was graded on a 1–5 Likert scale (1 = *strongly disagree*, 5 = *strongly agree*). In part (IV) to investigate the prevalence of MSDs, the standardized Nordic questionnaire (Kuorinka *et al*., 1987) was used. The correlation between demographic factors and MSDs was tested using Pearson correlation [Pearson, 1931]. In order to determine the impact of various ergonomics risk factors on MSDs development odds ratio (OR) is calculated. Heart rate meter was used to measure the heart rates and energy expenditure was calculated for classification of various jobs. For this purpose, Fingertip Pulse Oximeter was used. 2-D biomechanical prediction, RULA (Rapid Upper Limb Assessment) was used to investigate the exposure of individual workers to the different risk factors associated with upper limb disorders; analysis is done using Ergo Master™ software.

The primary objective of this study is to develop an instrument for the measurement of safety management practices identified from employees' perspective based on an empirical analysis. A measurement model has been designed for each safety management practice, and confirmatory factor analysis (CFA) has been run for all factors for checking unidimensionality, convergent validity, and reliability of the factors. Statistical programs SPSS™ 21 with AMOS were used for these analyses. The correlation between dimensions of safety management factors was tested using Pearson correlation.

Data is collected from 321 randomly selected workers from thirty-seven SMEs. Workers with more than one year of experience were considered for this study purpose. Out of 321 workers, 250 (77.88% response rate) had filled the questionnaires completely which were used for analysis purpose.

6. RESULTS AND DISCUSSION

Statistical analysis; Mean, mode values and standard deviations were calculated for each scale. The performance analysis included a discriminate analysis, internal consistency (reliability indicators), and construct validity (factor analysis). Correlation analysis and odds ratio (OR) was calculated. Internal consistency; Cronbach's alpha coefficient was calculated to assess the internal consistency or homogeneity of the questions aimed at measuring the same construct.

The analysis was carried out using SPSS version 21. The descriptive statistics was carried out to calculate the details of demographic factors along with prevalence percentage of MSDs of respondent workers. Pearson correlation was obtained to know the relationship between ERF and development of MSDs. Odds ratio shows the association and impact of various ERF with the development of MSD symptoms. All the workers were male and 90.84 % were married, with average age of workers was 31.32 (SD = 6.71) years. In respect of educational qualification,

29.08 % of workers had primary school education, 61.35% of workers had secondary school education and only 9.57% had the technical education.

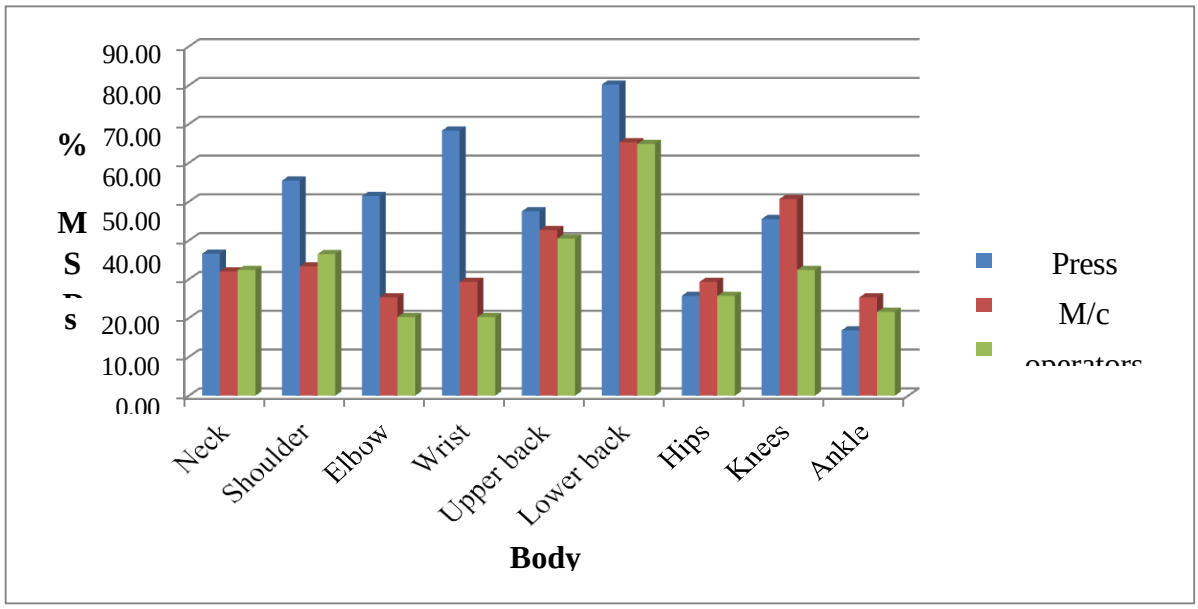

Figure 2 MSDs among different body parts

Response to ergonomics conditions based upon worker's response is analysed. It was observed that most of the workers agreed that they have to do manual work, bend/twist, and do the force exertion while working, also they have agreed that workplace layout is not comfortable and there is no foot rails and space for freely spreading the legs. Workers are involved in manual loading/unloading, load lifting, and insufficient mechanical aids, need modification in material handling equipment. It is observed that there is need of modification in the design of task and job- related factors. Study result shows that 70.92% of workers reported lower back pain followed by wrist/hand (45.82%), upper back (43.82%), shoulder and knee (43.02%), neck pain (33.86%) hips (26.75), and ankle (20.72). Poor working conditions, ergonomic workplace and the absence of an effective work injury prevention program has resulted in a high rate of MSDs among the workers. In India, there is a large group of the aged workforce who has become a part of work. The results of the study show that there was a statistically significant correlation between age, and experience with the development of MSDs among SME workers. Ergonomics risk factors like manual work, loading/unloading, load lifting, force exertion, and job rotation are found to be significant factors for the development of MSDs. Fig 2 shows MSDs reported by different workers. Press workers show highest pain reporting followed by welder and machine operators. Odds ratio (OR) shows that certain ERF not only contribute but have significant impact on the development of MSDs.

Energy expenditure was computed based upon heart rate to classify workload so that job rotation and variation in task among the workers is possible. It is observed that for the most of

workers heart rate is less than 100bts/min. Rapid Upper Limb Assessment (RULA) was carried for screening a large number of operators quickly, and the scoring system developed also provides an indication of the level of loading experienced by the individual body parts. ErgoMaster™ was used to find 2D biomechanical prediction of workers for anthropometry, biomechanical angles, and biomechanical predictions about L5/S1. The biomechanical predictions about L5/S1 show that large amount of total compressive force, total bending moment, and total joint reactive force due to adopted awkward posture; sitting without support, space constraints etc.

Safety management questionnaire analysis was done to find out the response of workers about safety in the organization. For the validity of the questionnaire, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was checked and values greater than 0.5 were considered as acceptable [Kaiser, 1974]. Cronbach's α value more than 0.7 is considered acceptable and expletory factor analysis was done and factors having a factor loading less than

0.4 were eliminated [Milijic *et al.* 2013; Ghahramani *et al.*2015]. Structural Equation Modeling (SEM) technique attempts to identify 'causal' processes. These processes are represented by a series of structural equations, which can also be modeled pictorially. A hypothesized model is tested statistically in a simultaneous analysis of all the variables, to determine the extent to which it is consistent with the observed data. The overall fit of the model was assessed using a number of fit indices. Statistical package AMOS was used for this purpose. Different alternate models were tested and the fit model was developed explaining the relationship among

various safety management's parameters. Fig 3 shows hypothesized model, stating relationship among different safety management factors.

Case study and Validation

System approach for ergonomics and safety management was applied to five small scale industries with following steps

- Low cost improvements; (Labels, posters, passageways, easy reach)
- Improvement in workstations, material handling; (Mobile racks, bins, carts, trolleys, chairs etc.)
- Multiple improvements; (Work conditions, safety committees, management involvement, training)
- Strategic approach; (Policies, goals, records, evaluation)

The result shows that there is an increase in ergonomic knowledge and awareness, decrease in MSD symptoms, reduced absenteeism, reduction in near miss and accident rate, improvement in work environment and increased awareness about safety management practices. Multiple work improvements are found to be useful in reducing the risk of musculoskeletal disorders and improving safety, health, and well-being of workers.

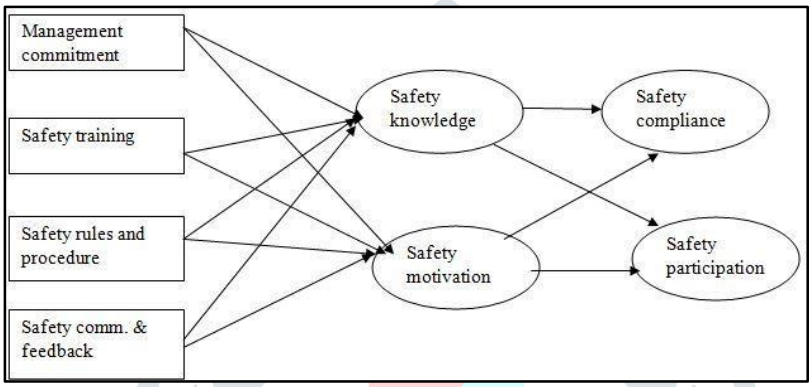

Fig 3 Hypothesized model

7. CONCLUSIONS

From the study of ergonomics and safety management practices in SMEs, ergonomics interventions and application of system approach to ergonomics and safety management practices in few SMEs, the major conclusions are summarized as below;

- It is concluded that press workers reported more uneasiness with the arrangement of tools, layout, material handling, and design of job and task related problems than welder and machine operators.
- Comparison of safety management practices adopted by different workers is grouped together; results show that machine operators have better safety culture than welder and press workers.
- MSD reported by workers is 67.6%. This large % of self-reporting of MSDs needs more physical /clinical examination of workers. It is observed that press workers reported highest amount of MSDs followed by machine operators, and welder.
- Different ERF like manual work, bend/twist, workplace layout, loading/unloading, repetitive work, load lifting, workplace condition were found to be significantly correlated (p<0.01, p<0.05 level) with the MSDs development.
- The accident rate was found to be significantly correlated with safety factors like; discussion with a supervisor, knowledge about work procedure, safety issues priority in training, knowledge about maintaining workplace safety and health, at p<0.05 level.
- Application of system approach for ergonomics and safety management found that there is a decrease in MSDs by 8.09%.
- Use of ergonomics principles and safety management practices resulted in reduction in absenteeism by 8.77%.
- Application of ergonomic approach and safety management practices resulted in improvement in labor productivity by 4.81%.

- Instrument and model was developed for evaluating the status of safety management practices in SMEs.
- Developed instrument for measuring safety management practices would be helpful for decision makers for designing and developing safety intervention programs.
- The research revealed the different factors like management contribution, training, safety rules and procedure, worker's involvement, safety knowledge, safety participation, safety motivation, safety compliance of safety culture among different SMEs.

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