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A Review on Ergonomics and Its Evaluation Techniques Used at Different Field-Areas

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ABSTRACT: This paper focuses on the study of the ergonomics aspects and various field areas on which ergonomics studies are carried out using different techniques and analysis. Human resource is the most valuable asset of any organization. Ergonomics is an important aspect in any industry for minimizing the human energy consumption and fatigue avoidance and maximization of human resources productivity efficiency and effectiveness during the work processes and activities they are involved in. high demand of the product in various industrial sectors had driven the worker to work faster and adapt to their un-ergonomically workstation and methods. Now, manufactures found that instead of investing lots of money on man, machine, material, method (4m), improving ergonomics of workplace is cost saving. The purpose of this study is to demonstrate the ability to interpret the various aspects of ergonomics contribution and influence in the industry and also various measurement techniques for the evaluation of same.

KEYWORDS: Ergonomics, postural analysis, working environment, NIOSH.

I. INTRODUCTION

Ergonomics- definition:

The term “ergonomics” is derived from two Greek words: *ergon*, meaning work, and *nomos*, meaning law. Therefore, ergonomics is a managerial multidisciplinary science that creates the principles that need to be followed in order to ensure productivity and work efficiency. Ergonomics is a holistic approach, as it takes into account physical, cognitive, environmental, social, organizational, and any other relevant factors (International Ergonomics Association) [1]. Ergonomics is the scientific study of man machine interaction at the workplace. The basic objective of ergonomics is to fit man and machine together to improve the worker's performance, reduce stresses and fatigue at work. Application of ergonomics is very significant in area where manual activities directly affect physical and mental health of the employee [2]. Ergonomics indicates the harmony among labor, machines and the environment. The main intention of ergonomic designs is to facilitate efficient mental and physical labor. To facilitate efficient labor, certain physical and mental attributes must be considered, for example, respiration, circulation, skeletal and muscle systems. In addition, working conditions should be organized according to these conditions. Ergonomics is also defined as the work design technology that investigates the relationship between humans and the environment [3]. Ergonomics is concerned with the man, machine and environment to be efficient, safe and comfortable as possible to operator. Effective application of ergonomics in workplace area can achieve a balance between worker and activity. This can enhance operator productivity; provide worker safety and physical and mental job satisfaction [4].

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Table1. A comparative overview of the major definitions of ergonomics [1]

No.	Author	Country	Definition
1	Murrell	Great Britain	Ergonomics is the scientific study of relationships between human and his working environment, considering working environment as constituted from the surrounding (external) environment, raw materials, tools, methods of working and organizing of the individual and collective workers' activities.
2	Metz	France	Ergonomics is the integrated ensemble of sciences that may provide information on human work necessary to rational adaptation of human to machines and of work to the human.
3	Cazamian	France	Science of human efficiency; industrial ergonomics aims to maximize this efficiency designing and transforming industrial work situations, using in this purpose a multidisciplinary method.
4	De jong	Netherland	Ergonomics is the application of biology knowledge in domains such as anatomy, experimental physiology and professional medicine with the purpose of reaching a certain "human-machine" optimal system.
5	Mihaila	Romania	Ergonomics is the science that synthesizes the results of applied human sciences, techno-economical and psycho-social sciences and applies them in the work process with the aim of increasing production, its quality and maintaining integrity of human personality.
6	International Labor Organization (ILO)	Switzerland	Ergonomics is a science that applies the knowledge in human biology in correlation with techno-economical sciences to reach a reciprocal optimal adaptation between human and his work, measurement of the result consisting in efficiency, and health indices.
7	International Ergonomics Association	Switzerland	"Ergonomics 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." (International Ergonomics Association)

Branches of ergonomics:

Physical ergonomics is concerned with human anatomy, and some of the anthropometric, physiological and bio mechanical characteristics as they relate to physical activity.

Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. This includes mental workload, decision making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design.

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Organizational ergonomics is concerned with the optimization of socio-technical systems. This includes organizational structures, policies, and their processes. Others relevant things includes communication, crew resource management, work design, work systems, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work programs, virtual organizations and quality management [5].

The method of evaluating complex work systems relies on 14 criteria grouped into 4 strenuousness categories

1. Physical working environment factors (noise, vibration, microclimate, lighting, dust levels, toxicity, electromagnetic radiation);
2. Physical strain factors (energy consumption, static strain, repetitiveness of motion);
3. Psychological strain factors (information overload, monotony);
4. Technological and organizational factors (factors related to workplace organization and technical equipment) [6].

II. RESEARCH METHODOLOGY

The aim of this study is to create an understanding towards the importance of the ergonomics and to identify different techniques for the ergonomic assessment. The research strategy was made by identifying the relevant data source, keyword and selecting research paper in which successful evaluation and assessment of ergonomics is carried out in different areas and using different techniques.

The initial part gives an overview of the ergonomics and its branches. In the next part few cases of places (available from established publications) where ergonomics assessments were successfully carried out are presented. However most of the research studies are not disclosed easily by the authors, we have taken 12 case studies to explore the concept. The study of all the cases is then compared and is presented in the following sequence

- 1) General overview of publications and the case industries.
- 2) Review of ergonomic evaluation methods and techniques
- 3) Techniques and methods used by case industries and Results gained by the same.

III. GENERAL OVERVIEW OF CASE INDUSTRIES

The table 2 below gives the publication name (i.e. research paper title), the field area or product in which ergonomics assessment carried out. The referred name on the left most column indicates the name by which the publication has been referred in the rest of the review paper. The table also gives information about the journal, authors' name and year of publication of the selected cases.

Table 2: An Overview of Case Industries

Referred Name	Title	Journal/conference Year	Author /Authors	Field-area/product and/or Description
A	Ergonomic assessment and workstation design of shipping crane cabin in steel industry.	International Journal of Industrial Ergonomics 2015	Deepak Kumar Kushwaha, Prasad V. Kane.	Integrated steel Plant located In central India/shipping crane

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B	Operational Improvement in The Assembly Process Of Lead Cable Using New Methods	World Conference On Technology, Innovation And Entrepreneurship 2015	Mehmet Alper Sofuoglu, Fatih Hayati Cakir, Selim Gürgen, Melih Cemal Kushan.	Cable manufacturing Company/ assembly process
C	Ergonomics Study to Improve Workstation Productivity In Manufacturing Sector	International Journal of Scientific Progress And Research 2015	Mahesh Kumar M D, Dr. BR Narendra Babu, Ganesh kumaran, Dr.K Chandra Shekara.	Rane Madras Pvt. Ltd, Mysore/steering gear box
D	Reducing Ergonomic injuries for librarians using a participatory approach	International Journal of Industrial Ergonomics 2015	Lu Yuan	East Baton Rouge Parish Main Library/librarians
E	Participatory ergonomics intervention for improving human and production outcomes of a Brazilian furniture company	International Journal of Industrial Ergonomics 2015	Lia Buarque De Macedon Guimaraes, Michel Jose Anzanello, Jose Luis Duarte Ribeiro, Tarcisio Abreu Saurin	Furniture manufacturing company in Southern Brazil/workstations
F	Ergonomic assessment of musculoskeletal disorders from load-lifting activities in building construction	International Journal of Advanced Engineering Technology E-ISSN 0976-3945 2014	Godwin, Harold Chuckwuemeka and Okpala, Charles Chikwendu	Building construction/lifting activities
G	Industrial Work Station design: An Ergonomic Approach to Number Punching Machine	International Journal of Current Engineering and Technology 2013	Samata Satish Mujumdar, Varsha Karandikar, S.M.Sane.	Automobile /Manual number punching machine
H	Ergonomics Intervention in an Iranian Tire Manufacturing Industry	International Journal of Occupational Safety and Ergonomics (JOSE) 2013	Majid Motamedzade	Tire manufacturing industry/Working area
I	Ergonomic Risk Assessment Using Postural Analysis Tools in a Bus Body Building Unit	Industrial Engineering Letters IISTE 2013	Qutubuddin S.M, S.S. Hebbal, A.C.S. Kumar.	Automotive Coach manufacturing company/Bus body building unit

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J	Ergonomics Assessment of Workstation design In automotive Industry	National Conference In Mechanical Engineering Research And Postgraduate Studies. 2010	A.R. Ismail, N. Jusoh, A.Z. Ismail M.H.AbuBakar, W.H. W. Deraman, A.P. Puvanasvaran.	Automotive Industry/Inspection Workstation
K	Ergonomics interventions to improve work environment in garment manufacturing units	Indian Journal of Occupational and Environmental medicine (IJOEM)	P. Parimalam, N. Kamalamma, A. K. Ganguli	Garment manufacturing units /Madurai city
L	Ergonomic Assessment of working postures in semiconductor manufacturing processes	National Symposium on Advancements in Ergonomics and Safety 2009	Abdul Shukor Abdullah, Mohd Nasrull Abd Rahman.	Semiconductor Manufacturing Processes.

IV. ERGONOMIC EVALUATION TECHNIQUES (REVIEW)

Postural analysis

One of the most prevalent occupational health problems, affecting millions of workers every year are Work-related musculoskeletal disorders (MSDs). Major causes of MSDs among workers are high physical demands, such as heavy lifting, repetitive motions, and awkward working postures (e.g., bending and twisting, kneeling, working with the arms above shoulder height) [7]. Different techniques are applied for postural analysis of work related musculoskeletal risk factors. These methods are Rapid Upper Limb Assessment Method (RULA) method and Rapid Entire Body Assessment (REBA) method and quick exposure check (QEC).

RULA (Rapid Upper Limb Assessment): The Rapid Upper Limb Assessment (RULA) was developed earlier by McAtamney and Corlett, to provide a rapid objective measure of musculoskeletal risk caused by mainly sedentary tasks where upper body demands were high and where work related upper limb disorders are reported. It is a screening tool that assesses biomechanical and postural loading on the body. It focuses on the neck, trunk and upper limbs, and is ideal for sedentary workers. It is a simple, quick and easy to complete.

The use of RULA results in a risk score from one to seven, where higher scores signify greater levels of apparent risk. Briefly, the upper arm, lower arm, and wrists postures are evaluated and scores are given for each body part posture. Then, the scores are combined (using a specially developed scoring table). To generate the upper limb posture score. Similarly, the neck, trunk, and legs postures are evaluated and scores are also given. They are combined to generate the neck-trunk-legs score. For both combined scores, scores for muscle use and force are added. Finally, the grand score is determined and action to be taken is recommended [8] [9].

REBA (Rapid Entire Body Assessment): The RULA and REBA both are similar tools for evaluate the musculoskeletal disorders. REBA is an ergonomic assessment tool uses an orderly process to evaluate whole body postural MSD and risk associated with workplaces. Hignett and McAtamney (2000) introduce REBA and stated that it is used to investigate posture for risk of work related musculoskeletal disorders (WRMSDs). Postures of individual body parts are observed and postural scores increase when postures diverge from the neutral position.

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Group A includes trunk, neck, and legs, while group B includes upper and lower arms and wrists. Other items including the load handled, couplings with the load, and physical activity are specifically scored and then processed into a single combined risk score using a table provided. These scores are summed up to give one score for each observation, which can then be compared to tables stating risk at five levels, leading to the necessity of actions. Unlike RULA, REBA provides five action levels for estimating the risk level. These risks levels starting from 0 to 4 are corresponding to negligible, low, moderate, high and very high risk level respectively [10][11].

Quick Exposure Check (QEC): QEC is used to assess the level of exposure to ergonomic risks. Quick Exposure Check (QEC) is an observational method that was developed by Li and Buckle in 1998. Information about maximum weight handled, time spent on task, level of hand force, application of vibrating tools, visual demand of the task and difficulties to sustain with the work as well as the stressfulness of the work are also obtained from the worker. The method includes the assessment of the back, shoulder/upper arm, wrist/hand and neck, with respect to their postures and repetitive movement.

The QEC checklist/assessment sheet includes questions that need to be answered by both the user and the worker. These questions are designed to quantify the exposure risk for the four main areas of the body (back, shoulder/arm, wrist, and neck). The ratings are weighted into scores and added up to summary scores for different body parts and other items driving, vibration, work pace, and stress. In QEC to achieve an overall score, total scores obtained from four body parts are added and the product is divided by the maximum possible score. Finally, QEC provides 4 categories for estimating the risk level. These risk levels are named from 1 to 4 i.e. low, moderate, high and very high risk level respectively [12][13]. The classification of risks according to RULA, REBA and QEC is shown in Table 3.

Table 3. Classification of Risks according to Scores of Assessment Tools

RULA		REBA			QEC	
RULA Score	Action Required	Action level (Risk level)	REBA Score	Corrective Measure	QEC Score %	Action required
1-2	Acceptable	0 (Negligible)	1	None Necessary	$\leq 40\%$	Acceptable
3-4	Change may be necessary	1 (Low)	2-3	May be Necessary	41-50%	investigate further
5-6	Change Necessary soon	2 (Medium)	4-7	Necessary	51-70%	investigate further and change soon
7	Change Immediately	3 (High)	8-10	Necessary Soon	$> 70\%$	investigate and change immediately
		4 (Very High)	11-15	Necessary Now		

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Participatory ergonomics

Participatory ergonomics (PE) is defined as “the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals”.

Another definition of PE is “practical ergonomics with participation of the necessary actors in problem solving” Forming a team or a committee is the main feature of most PE interventions.

Forming intervention teams is essential to conduct an ergonomics intervention. Teams typically involve workers or their representatives, managers, ergonomists, and health and safety personnel. Teams usually receive training from an ergonomist to become familiar with ergonomics principles. They use their newly developed knowledge to improve their workplace [14].

Methods for Finding Safe Load Limits for Manual Material Handling Tasks

The revised National Institute for Occupational Safety and Health (NIOSH) Lifting equation is employed for the calculation of the Recommended Weight Limits (RWL), and Lifting Index (LI).

The NIOSH lifting equation provides a method for determining the risks associated with weight lifting. The Lifting Index (LI) is used to estimate the risk of specific lifting tasks in developing low-back disorders. Also the recommended weight limit (RWL) is the load value for a specific lifting task that nearly all healthy workers could perform for a substantial period of time without an increased risk of developing lifting-related pain and is calculated as follows.

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \quad (1)$$

LC = Load Constant of 23 kg (51 lbs) and where each multiplier can assume a value between 0 and 1.

HM = Horizontal Multiplier: H is the horizontal location (distance) of the hands from the midpoint between the ankles at the start and end point of the lift.

VM = Vertical Multiplier: V is the vertical location (height) of the hands above the floor at the start of and end of the lifting point.

DM = Distance Multiplier: D is the vertical travel distance from the start to the end point of the lift.

AM = Asymmetry Multiplier: A is the angle of asymmetry, i.e. – the angular displacement of the load from the medial, which forces the operator to twist the body. It is measured at the start and end point of the lift, projected onto the floor.

FM = Frequency Multiplier: F is the frequency rate of lifting, expressed in lifts per minutes. It depends on the duration of the lifting task.

CM = Coupling Multiplier: C indicates the quality of coupling between hand and load [15].

Environmental Measurement Techniques

It involves noise, vibration and illumination.

Noise: It is the most important ergonomics problem in factories. Compared to many other ergonomic problems noise is very obvious and concrete.

Four different aspects making noise unacceptable in the working environment:

1. Noise can cause hearing loss
2. Noise can affect performance and productivity
3. Noise can be annoying
4. Noise can interfere with spoken communication

OSHA (1981 & 1983) gave the sound level with exposure time explain below:

The human can bear 95 dBA level of sound for 3.5 hr, 105 dBA level of sound for 0.5 hr and 85 dBA level of sound for 4 hr. A sound level meter or sound meter is an instrument that is used for measuring sound pressure level [5].

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Illumination: A well-designed illumination system is important for industrial productivity and quality, as well as operator performance, comfort, and convenience. Three important design factors need to be considered these are:

Illumination- The amount of the lighting falling on a surface.

Luminance- the amount of light reflected or emitted from a surface.

Luminous contrast ratio- the difference between the luminance values of the adjacent areas, assuming that there is a defined boundary between them. Kaufman and Christensen (1984) gave some of the guidelines to be followed are -

Select a light intensity of 10-200 lux for orientation tasks.

Select a light intensity of 200-800 lux for normal activities.

Select a light intensity of 800-3000 lux for special applications.

Illuminance is measured by a luxmeter, which is a handy instrument with a sensor. The measured Illuminance is directly displayed in lux (lx).[5]

Vibration: Like other hazards at work vibration needs to be identified as a problem and controlled. Laboratory studies have confirmed that vibrations between 3 and 5 Hz are likely to be physically uncomfortable. Moderate level of vibration causes an increase in heart rate, about 10–15 beats/min above the resting level. The heart rate returns to its normal level after the vibration ceases. Blood pressure can also increase, particularly for vibration frequencies around 5 Hz. Some investigations have revealed a slightly increased breathing rate and oxygen consumption. Vibration is measured by Digital Vibration Meters, Analog Vibration Meters, Transmitters and Monitors [5].

V. TECHNIQUES USED BY CASE INDUSTRY AND RESULTS GAINED BY THE SAME

Table 4: Methods/techniques adopted and Results gained

Referred name	Methods/techniques adopted	Results
A	Postural analysis(RULA)	Ergonomic assessment has revealed the root causes of MSD & based on the information revealed, the existing cabin design is modified with ergonomic analysis.
B	Sufficient illumination, optimum access and working area.	Newly improved processes and machine systems were proposed. Unnecessary work was eliminated, and a significant gain in time was obtained.
C	Postural analysis(RULA)	Ergonomically improved workplace layout helps in reduced stress on workers, elimination of repetitive tasks, cycle time reduction and hence increased productivity.
D	Participatory approach	The results of this study provide a necessary foundation for future long-term study of participatory ergonomics to reduce musculo-skeletal injuries and disorders for librarians.

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E	Participatory approach	The tested cellular model reduced workload in 42% and postural risk decreased from OWAS level 4 or 3 to level 2. It required 35% less time to assembly wooden frames and straps, and 32.2% less time to perform foam-gluing operations
F	NIOSH lifting equation	Significant decrease in the lifting index associated in lifting various loads, Thereby enhancing the good health of the workers, improve productivity, drastically reduce the risks of the spread of musculoskeletal disorders among the workforce, as well as work-related injuries.
G	Direct observation, video recording and input from experienced personnel.	Replacement of human operators in tasks that involve hard physical or monotonous work. Safety Quality improvement.
H	participatory ergonomics	Improvement in working conditions.
I	RULA, REBA, QEC	Evaluation of High risk of the various Work-related Musculoskeletal disorders (WMSDs) in the working methods in the bus body building company.
J	Questionary survey Anthropometry analysis	Adequate posture, work height, normal and maximum working areas are determined
K	Optimum Working height, environment measurements such as noise, heat.	These interventions made in the units would help to improve the work environment of the garment manufacturing units
L	Postural analysis (REBA)	Overcome the high risks of injury to the operators.

VI. CONCLUSION

From the research reported by different researchers it can be concluded that ergonomics is an important criteria that must be included in any industry for achieve human comfort and satisfaction. Although different ergonomics evaluation techniques were used in different fields but still there is lack of ergonomic awareness in many industries. So these techniques can be helpful for ergonomic evaluation at the workplaces. Also there should be an adaptation of proactive ergonomics such as consideration of human properties, abilities and skills by means of methodological procedure in the planning, conception and design phase of work system t for the avoidance of ergonomic issues.

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