PSYCHOLOGY AND EDUCATION (2024) 61(4): 85-94
ISSN: 1553-6939

Study and Assessment of Workplace Ergonomics in Manufacturing Industry

Bindhu A S[1*], Rajath R Rao[2]
[1]Assistant Professor, Department of mechanical engineering, JSSSTU, SJCE
[2] EHS Specialist, LabCorp Laboratories India Pvt Ltd
*bindhupatel@jssstuniv.in

ABSTRACT

This study delves into the critical aspect of workplace ergonomics within the manufacturing industry. Ergonomics, the science of designing environments and tools to fit human capabilities and limitations, plays a pivotal role in enhancing worker health, safety, and productivity. In the context of the manufacturing sector, where workers are often exposed to physically demanding tasks and repetitive motions, optimizing ergonomics is paramount.

Furthermore, this research endeavours to quantify the economic impact of ergonomic improvements by examining factors such as reduced absenteeism, increased productivity, and healthcare cost savings. By employing both qualitative and quantitative methodologies, including surveys, ergonomic assessments, and financial analyses, this study aims to provide a holistic understanding of the significance of workplace ergonomics in the manufacturing sector.

The findings of this study are expected to offer valuable insights to manufacturing industry stakeholders, including employers, policymakers, and occupational health professionals, facilitating evidence-based decision-making and resource allocation towards creating safer, healthier, and more efficient work environments. Ultimately, by prioritizing ergonomic principles, manufacturing organizations can foster a culture of safety and well-being while simultaneously enhancing operational performance and competitiveness in the global market.

Keywords
Workplace Ergonomics, Ergonomic Risk Factors, Manufacturing Industry, Productivity, Health and Safety, Ergonomic Assessments, Financial Analysis, Operational Performance, Employee Training.

Introduction

The word Ergonomics comes from two Greek words:
ERGO: meaning work
NOMOS: meaning law
Ergonomics is the science of "designing the job to fit the worker, not forcing the worker to fit the job." Ergonomics covers all aspects of a job, from the physical stresses it places on joints, muscles, nerves, tendons, bones and the like, to environmental factors which can affect hearing, vision, and general comfort and health, when there is a mismatch between the physical requirements of the job and the physical capacity of the worker, work-related musculoskeletal disorders (WMSDs) can result.

Physical stresses include repetitive motions such as those caused by typing or continual use of a manual screwdriver. Other physical stresses could be tasks involving vibration such as using a jackhammer, or tasks which involve using excessive force, such as lifting boxes of heavy books. Working in an awkward position, such as holding a telephone to your ear with your shoulder, can also cause problems. Repetitive motions, vibration, excessive force, and awkward positions are frequently linked to ergonomic disorders; however, the majority of "Cumulative Trauma Disorders "(CTDs) or "Repetitive Strain Injuries" (RSIs) are caused by repetitive motions that would not result in undue stress or harm if only performed once.

Ergonomics also known as" human engineering". It evaluates the combined effect of all these interacting factors on productivity. successful application of such tools and techniques of the domain of ergonomics may lead to the development of the most comfortable working conditions in terms of illumination, climatic condition, noise level which ensures the minimization of physical work load, to improve work posture as well to reduce the effort of certain movements.

Ergonomics can be defined simply as the study of work. More specifically, ergonomics is the science of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job. Adapting tasks, work stations, tools, and equipment to fit the worker can help reduce physical stress on a worker's body and eliminate many potentially serious, disabling work related musculoskeletal disorders (MSDs). Ergonomics draws on a number of scientific disciplines, including physiology, biomechanics, psychology, anthropometry, industrial hygiene, and kinesiology.

Literature Review

The purpose of this literature review is to gain insight into Ergonomics and how it can be applied within a manufacturing environment. With global competition, it is important for manufacturers to

remain competitive in their respective markets and to understand the principles of Ergonomics and the steps to implement them to ensure that they are on the leading edge of manufacturing. This literature review describes these key principles.

Ergonomics and real demand from companies all want their workplaces are promoters of productivity and quality; for this, it needs a correct relationship between environmental factors (lighting, noise, temperature), developed effort, postures, repetitiveness and tools Currently, human resources and the cost of labour have greater impact on organizations, so it is important to facilitate work and make workers more productive.

Ergonomics is the scientific study of mane machine interaction at 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 handling of shipping and transferring is one such activity in which physical and mental health plays a very vital role. A handling operator has to perform various activities, such as continuous monitoring of handling of shipping and transferring operation i.e. loading and unloading of heavy steel billets & plates, adjustment of end effectors by using specific control levers embedded in a closed cabin. The task of operator is highly repetitive.

Table 1. Literature Review

Authors	Paper title	Discussion
Alan Hedge and Jonathan Puleio	"Proactive Office Ergonomics Can Increase Job Satisfaction and Employee Retention" dated Tuesday, September 9, 2014	surveyed more than 200 employees at a software company that was relocating to a new facility with a proactive program that included ergonomic workstations, group training, and one-on-one consultations. Participants offered their opinion on how this new program compared with their former workplace, which did not provide ergonomic equipment or routine assessments. After the relocation, employees reported significantly less musculoskeletal and visual discomfort and higher levels of job satisfaction and happiness. They also said they thought the ergonomics program would likely enhance company retention and recruitment.
Federal Register	"Need for an Ergonomics Program Standard" Vol. 65, No. 220 / Tuesday, November 14, 2000 /	Work-related musculoskeletal disorders (MSDs) currently account for one-third of all

	Rules and Regulations	occupational injuries and illnesses reported to the Bureau of Labor Statistics (BLS) by employers every year. Although the number of MSDs reported to the BLS, like all occupational injuries and illnesses, has declined by more than 20% since 1992, these disorders have been the largest single job- related injury and illness problem in the United States for the last decade, consistently accounting for 34% of all reported injuries and illnesses. In 1997, employers reported a total of 626,000 lost worktime Workers with severe MSDs often face permanent disability that prevents them from returning to their jobs. This resulted in implementing ergonomic assessment in industries. There are a number of ways to measure the magnitude of exposure quantitatively. For work-related upper extremity MSDs the Rapid Upper Limb Assessment (RULA) evaluation tool is often used to investigate and evaluate jobs.
Ashraf A. Shikdar, Naseem M. Sawaqed	Worker productivity, and occupational health and safety issues in selected industries	lack of ergonomics knowledge and awareness of the employers and employees could have been responsible for the poor acceptance of ergonomics in the workplace. Management did not check the workplaces for unsafe features and did not enforce safety rules, or provide instructions and training for safe performance. Poor ergonomic conditions in industry not only hinder productivity but also affect health and safety of

workers and the quality of work and products. Ergonomically designed equipment and proper safety training can significantly reduce accidents. In most industries equipment is never assessed in terms of ergonomics. These are, obviously, potential hazards and the sources of injuries in industries.

Topic

The study and assessment of workplace ergonomics in the manufacturing industry encompass the systematic examination of how tasks, tools, and work environments interact with the capabilities and limitations of workers. This involves analyzing various factors such as posture, repetitive movements, force exertion, and environmental conditions to identify potential risk factors for musculoskeletal disorders and other health issues. Through methods like ergonomic audits, surveys, and biomechanical analyses, data is collected to pinpoint areas needing improvement. Recommendations for ergonomic enhancements, such as workstation redesign or changes to work processes, are then developed and implemented with the goal of enhancing worker safety, comfort, and productivity. Continuous evaluation and refinement ensure that ergonomic interventions remain effective and adaptable to evolving manufacturing practices and technologies.

Workstation Design and Layout

Workstation design and layout play a crucial role in ensuring optimal ergonomics in the manufacturing industry. This subtopic involves assessing the arrangement of workstations, tools, and equipment to minimize physical strain and maximize efficiency. Ergonomic evaluations focus on factors such as the height and positioning of work surfaces, the placement of tools within easy reach, and the configuration of seating to support proper posture. By optimizing workstation design, ergonomic experts aim to reduce the risk of musculoskeletal disorders, enhance productivity, and improve worker comfort and satisfaction. Recommendations may include adjusting workstation heights to accommodate varying worker heights, installing ergonomic chairs with lumbar support, and organizing tools and materials to minimize repetitive reaching and bending motions. Additionally, ergonomic assessments may involve considering factors such as lighting, noise levels, and environmental conditions to create a workspace that promotes overall well-being and safety for manufacturing employees.

Ergonomic assessment methods

• The Rapid Upper Limb Assessment (RULA) was developed to evaluate ergonomic exposures of the upper body. The range of motion for each body part (upper arms, lower arms, wrists, neck) is rated based on the amount of posture deviation. Posture combinations are ranked to reflect musculoskeletal loading with force, static work and repetition factors. RULA and documentation supporting it has been published in a peer-reviewed scientific journal. Areas of the body addressed: Wrists, Forearms/elbows, Shoulders, Neck, Trunk Risk factors evaluated: Awkward posture, force, repetition. Examples of jobs

that RULA is applicable to or well-designed for: assembly and production work, janitorial and maintenance, meatpacking, restaurant, grocery cashier, telephone operator.

• The Rapid Entire Body Assessment (REBA) is similar to RULA, but it has been modified to be more useful for the working postures found in the health care and other service industries. REBA and documentation supporting it has been published in a peer-reviewed scientific journal. Areas of the body addressed: Wrists, Forearms/elbows, Shoulders, Neck, Legs/knees, Trunk Back Risk factors evaluated: Awkward posture, force (load and coupling), repetition.

• The Workplace Ergonomic Risk Assessment (WERA), which is an observational tool was developed to provide a method of screening the working task quickly for exposure physical risk factor associated with Work-related Musculoskeletal Disorders (WMSDs). The WERA tool cover the six physical risk factors including posture, repetition, forceful, vibration, contact stress and task duration and its involve the five main body regions (shoulder, wrist, back, neck and leg). It has a scoring system and action levels which provide a guide to the level of risk and need for action to conduct more detailed assessments. This tool has been tested on its reliability, validity and usability during the development process. As the WERA tool is a pen and paper technique that can be used without any special equipment, it also can be done in any space of workplaces without disruption to the workforce.

Methodology

1.10.1 Ergonomic Assessment

A detailed workplace ergonomics survey or assessment using appropriate and relevant risk analysis tools. These tools include assessment tools like:

• RULA - Rapid Upper Limb assessment
• Workplace assessment

Standard Operating Procedure (SOP) For RULA Assessment

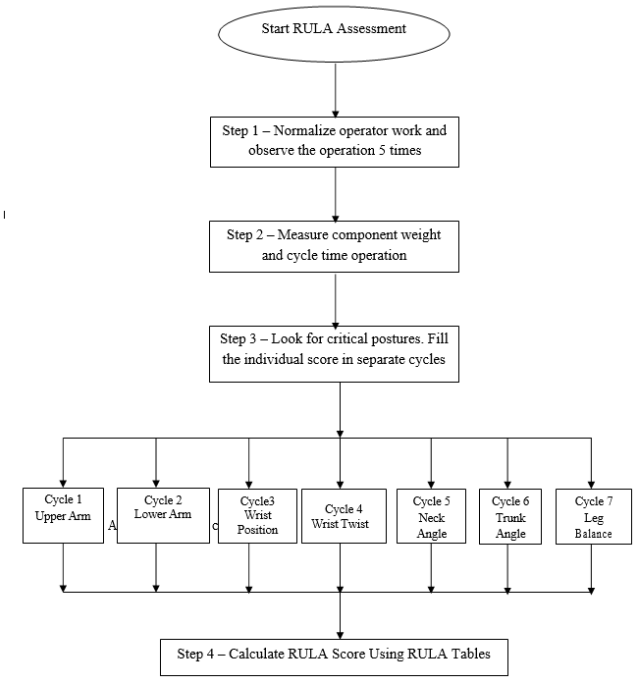


Fig 1: Methodology

Ergonomic Workplace Assessment

Poor working postures, repetitive tasks and heavy workloads can lead to increased risk of workplace injuries. An Ergonomic assessment can identify these risk factors by using a variety of data capture and risk assessment tools. By performing an Ergonomic assessment, the business can benefit from:

• Prevent costly litigation
• Comply with health and Safety citations
• Decrease injury risk, error rates and lost working days.
• Increase efficiency and productivity

A Workplace Assessment can help determine what is working effectively in an organization and what is not and assists all levels of employees to become aware of issues; to accept these issues are creating problems, and to take action to resolve them. The main objective of a Workplace Assessment initiative is to allow an organization to take action to address issues perceived to be a source of high conflict or creating a high level of dissatisfaction within the work environment. A Workplace Assessment also identifies what is working well within an organization. This allows an organization to fully leverage these strengths and further provides a means of promoting the continued use of these desired behaviors and practices among its workforce.

Workplace audit - Essentials
RULA is applicable for human postural assessment only. Effect of surrounding system not addressed.
It covers the major areas, for a concerned workstation

- Controls and displays.
- Lightings
- Material Handling
- Surrounding Environment.

Data Analysis

Demographic profile of the employees is obtained by the Frequency Analysis in Descriptive Statistics. In the study made, the major dimensions of demographic profile considered are gender, age, education, working period in company, nature of employee, variety in job, familiarity in concept, perception on ergonomics and rating of ergonomics training. These dimensions for demographic profile are given below from table 4.1 to 4.8

Gender

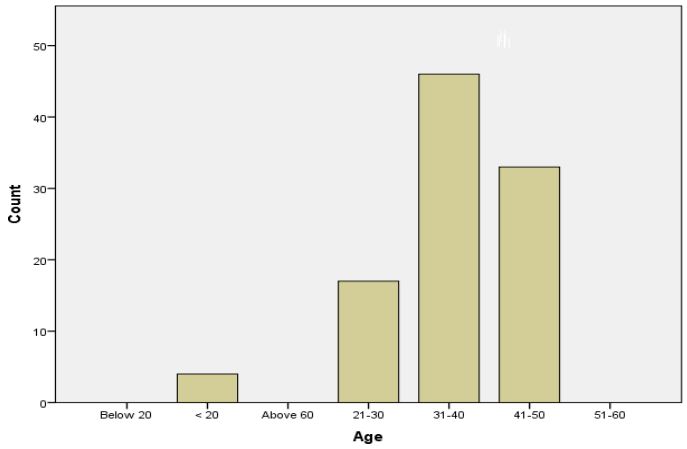
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	19	19.0	19.0	19.0
	Male	81	81.0	81.0	100.0
	Total	100	100.0	100.0	

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 20	4	4.0	4.0	4.0
	21-30	17	17.0	17.0	21.0
	31-40	46	46.0	46.0	67.0
	41-50	33	33.0	33.0	100.0
	Total	100	100.0	100.0	

From the graph below we can see that:

- There are no employees above 50 years of age.
- About 46% of employees working on the shop floor are aged between 31-40.
- There are 4%, 17%, 33% of employees below 20, between 21-30, 41-50 respectively.



Education

		Frequency	Percent	Valid Percent	Cumulative Percent
	Diploma	74	74.0	74.0	74.0
	ITI	26	26.0	26.0	100.0
	Total	100	100.0	100.0	

How long have you been working in the company?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 1 year	15	15.0	15.0	15.0
	1-5 years	11	11.0	11.0	26.0
	6-10 years	50	50.0	50.0	76.0
	10-15 years	10	10.0	10.0	86.0
	Above 15 years	14	14.0	14.0	100.0
	Total	100	100.0	100.0	

Are you a permanent or temporary or a trainee employee?

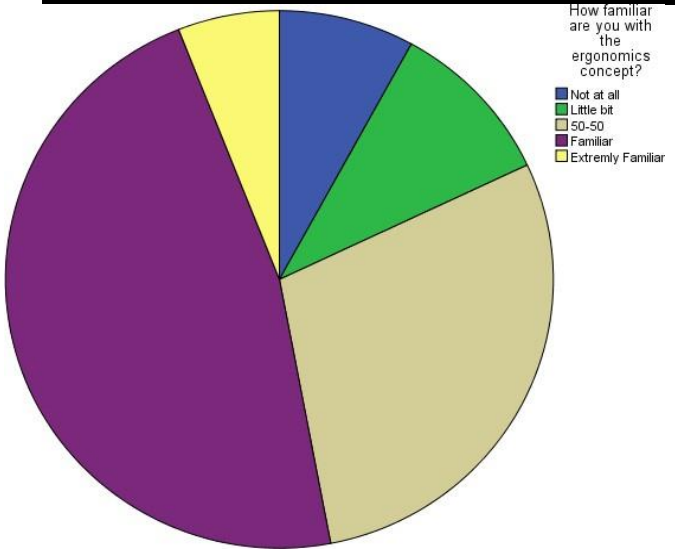
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Permanent	79	79.0	79.0	79.0
	Temporary	5	5.0	5.0	84.0
	Trainee	16	16.0	16.0	100.0
	Total	100	100.0	100.0	

In thinking about the variety of jobs you perform, do you think they are:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Enough	86	86.0	86.0	86.0
	Not Enough	5	5.0	5.0	91.0
	Too many	9	9.0	9.0	100.0
	Total	100	100.0	100.0	

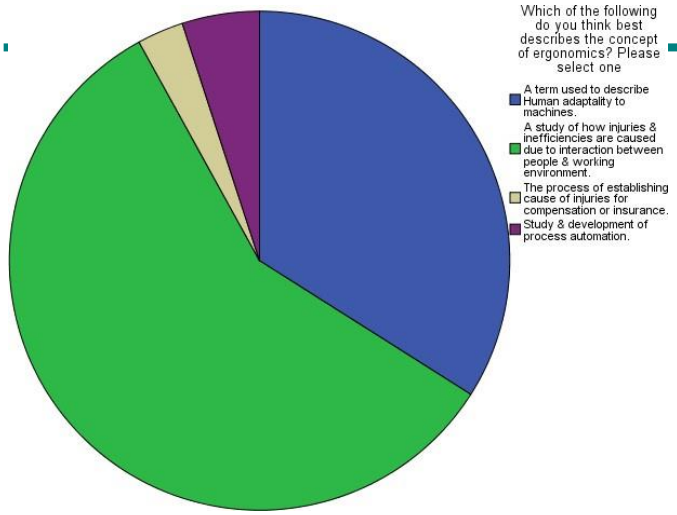
How familiar are you with the ergonomics concept?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	8.0	8.0	8.0
	Little bit	10	10.0	10.0	18.0
	50-50	29	29.0	29.0	47.0
	Familiar	47	47.0	47.0	94.0
	Extremely Familiar	6	6.0	6.0	100.0
	Total	100	100.0	100.0	



Only 49% of the employees know about the concept of ergonomics.

	Frequency	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A term used to describe Human	34	34.0	34.0	34.0
	A daptality to machines.	58	58.0	58.0	92.0
	A study of how injuries & inefficiencies are caused due to interaction between people & working environment.	3	3.0	3.0	95.0
	The process of establishing cause of injuries for compensation or insurance.	5	5.0	5.0	100.0
	Study & development of process automation.				
	Total	100	100.0	100.0	



Ergonomics training provided.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Can Improve	33	33.0	33.0	33.0
	Good	63	63.0	63.0	96.0
	Poor	4	4.0	4.0	100.0
	Total	100	100.0	100.0	

Forces on N.T.L	100	1.00	3.00	2.4700	.59382
Labelling of Controls	100	1.00	3.00	2.8000	.51247
Accessibility of Controls including emergency controls & Logical arrangement of controls and Displays	100	2.00	3.00	2.9400	.23868
Color coding for gauge displays(R/Y/G)	100	2.00	3.00	2.9300	.25643
Position of displays wrt eye level	100	2.00	3.00	2.9800	.14071
Operability of controls when operator has gloves	100	1.00	3.00	2.9500	.26112
Material flow through gravity	100	1.00	3.00	2.8000	.51247
Proximity of rack or trolley wrt operator	100	2.00	3.00	2.9400	.23868
Orientation of job wrt operation	100	2.00	3.00	2.9300	.25643
Position of displays wrt eye level	100	2.00	3.00	2.9800	.14071
Floor condition at workplace	100	2.00	3.00	2.9800	.14071
Access to machine	100	1.00	3.00	2.9500	.26112
Trolley handle design location	100	2.00	3.00	2.9900	.10000
Ambient noise at workplace	100	1.00	3.00	2.8000	.51247
Frequency of high pitch noise	100	2.00	3.00	2.9400	.23868
Temperature at workplace	100	2.00	3.00	2.9300	.25643
Relative humidity at workplace	100	2.00	3.00	2.9800	.14071
Fresh air circulation at workplace	100	1.00	3.00	2.9500	.26112
Adequacy of light for workplace & display without glare	100	2.00	3.00	2.9900	.10000
Contrast in highlighting safety critical areas	100	2.00	3.00	2.7900	.40936
Valid N (list wise)	100				

Results

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Upper Arm Right	100	1.00	3.00	2.8000	.51247
Upper Arm Left	100	2.00	3.00	2.9400	.23868
Lower Arm Right	100	2.00	3.00	2.9300	.25643
Lower Arm Left	100	2.00	3.00	2.9800	.14071
Wrist Right	100	1.00	3.00	2.9500	.26112
Wrist Left	100	2.00	3.00	2.9900	.10000
Wrist Twist Right	100	2.00	3.00	2.7900	.40936
Wrist Twist Left	100	2.00	3.00	2.9500	.21904
Muscular Force Right	100	2.00	3.00	2.8800	.32660
Muscular Force Left	100	1.00	3.00	2.8900	.34510
Neck Position	100	1.00	3.00	2.5400	.64228
Trunk Position	100	1.00	3.00	2.6200	.56461
Legs Position	100	1.00	3.00	2.4900	.67412

Mean ergonomic satisfaction of SGP plant is 2.87. Minimum score is 1 which implies “ALERT”and maximum is 3 which implies “COMFORTABLE”.

Correlations

		ergonomic score	arm & wrist	neck,trunk & legs	control & display	material handling	surrounding environment
Pearson Correlation	ergonomic score	1.000	-.762	-.302	-.744	-.606	-.544
	arm & wrist	-.762	1.000	.199	.785	.551	.492
	neck,trunk & legs	-.302	.199	1.000	.152	.087	.075
	control & display	-.744	.785	.152	1.000	.714	.533
	material handling	-.606	.551	.087	.714	1.000	.728
	surrounding environment	-.544	.492	.075	.533	.728	1.000
Sig. (1-tailed)	ergonomic score	.	.000	.001	.000	.000	.000
	arm & wrist	.000	.	.023	.000	.000	.000
	neck,trunk & legs	.001	.023	.	.065	.194	.228
	control & display	.000	.000	.065	.	.000	.000
	material handling	.000	.000	.194	.000	.	.000
	surrounding environment	.000	.000	.228	.000	.000	.
N	ergonomic score	100	100	100	100	100	100
	arm & wrist	100	100	100	100	100	100
	neck,trunk & legs	100	100	100	100	100	100
	control & display	100	100	100	100	100	100
	material handling	100	100	100	100	100	100
	surrounding environment	100	100	100	100	100	100

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.825[a]	.681	.664	.49071	.681	40.172	5	94	.000	1.723

a. Predictors: (Constant), surrounding environment, neck, trunk & legs, arm & wrist, material handling, control &display

b. Dependent Variable: ergonomic score

From adjusted R square, we find that there is 66.4% variance.

	Significance	Inference
Arm & wrist	0.00	Accept null hypothesis
Neck, leg trunk	0.01	Accept null hypothesis
Control & display	0.00	Accept null hypothesis
Material handling	0.00	Accept null hypothesis
Surrounding environment	0.00	Accept null hypothesis

Significance is <0.05 means we accept null hypothesis that "there is correlation between the ergonomic condition at workplace to the satisfaction level of the operator with respect to ergonomics."

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.365	5	9.673	40.172	.000[b]
	Residual	22.635	94	.241		
	Total	71.000	99			

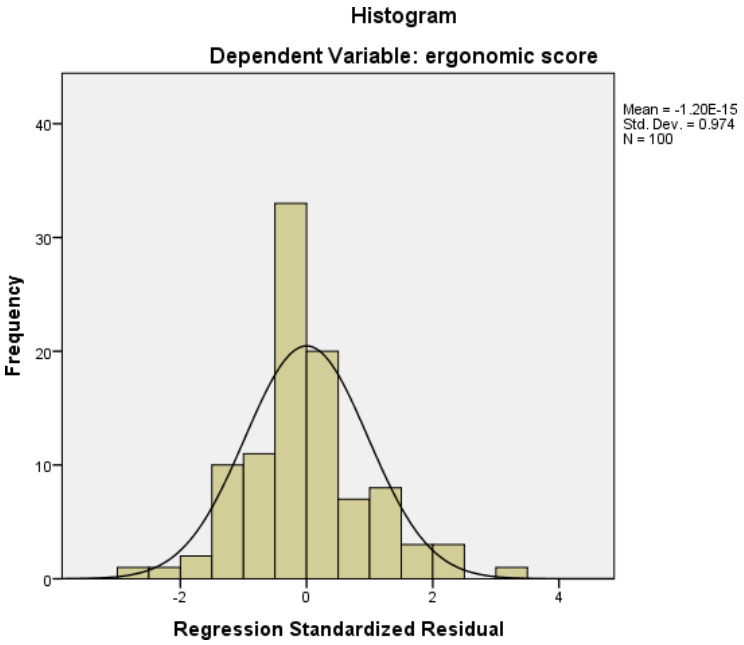
a. Dependent Variable: ergonomic score

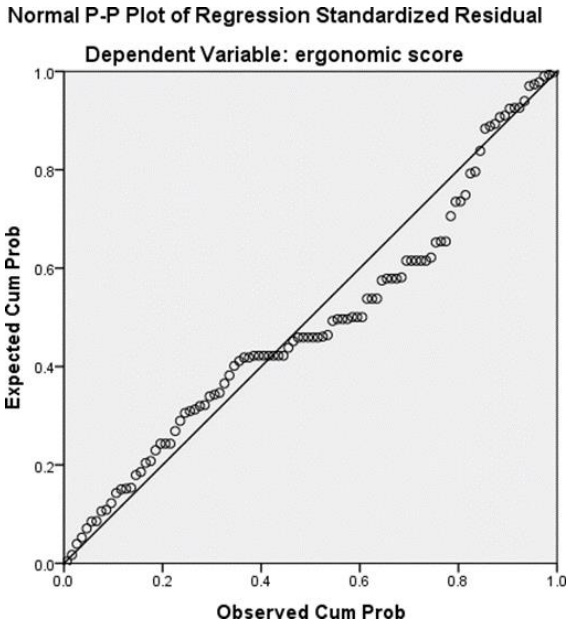
Predictors: (Constant), surrounding environment, neck,trunk & legs, arm & wrist, material handling, control & display

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	15.794	.836		18.881	.000	14.133	17.455
arm & wrist	-.194	.046	-.405	-4.197	.000	-.286	-.102
neck,trunk & legs	-.097	.035	-.163	-2.738	.007	-.168	-.027
control & display	-.218	.088	-.279	-2.473	.015	-.394	-.043
material handling	-.034	.046	-.075	-.728	.469	-.126	.058
surrounding environment	-.051	.034	-.129	-1.488	.140	-.119	.017

a. Dependent Variable: ergonomic score





From the regression analysis, the predictor equation is obtained as

Y=15.794-0.194A-0.097N-0.218C-0.034M-0.051S

Where A-arm & wrist, N-neck, trunk & legs, C-control & display, M-material handling, S-surrounding environment satisfaction levels and Y is ergonomic scores.

This is of the form"

Y=A+A1X1+A2X2+A3X3+A4X4+A5X5

Here, A, A1, A2, A3, A4, A5 are constants and X1, X2, X3, X4, X5 are variables.

Conclusion

Linear regression of ergonomic score vs ergonomic satisfaction is shown above. It can be seen that as ergonomic condition is improved at workplace ie decrease in ergonomic score results in increase of satisfaction level of the operator. This means that the operator feels more comfortable in working.
This means that the operator feels more comfortable in working.
The ergonomic satisfaction of the operator with respect to ergonomic score is given by equation
Y=15.794-0.194A-0.097N-0.218C-0.034M-0.051S
With this equation we can predict whether the operator working on a machine is feeling comfortable or not.

Future Studies

- The research was only limited to ergonomic satisfaction of the operator. Further it can be applied to overall job satisfaction.
- The performance can also be measured and further analysis can be made to find out impact on performance as well.

References

[1] Hignett, S., McAtamney, L. (2000). Rapid entire body assessment (REBA). Applied Ergonomics, 31(2), 201-205. doi:10.1016/s0003-6870(99)00039-3.

[2] Chaffin, D. B., & Andersson, G. B. (1991). Occupational biomechanics (2nd ed.). John Wiley & Sons.

[3] Konz, S., & Johnson, S. K. (2009). Ergonomics and the management of musculoskeletal disorders (4th ed.). Butterworth-Heinemann.

[4] National Institute for Occupational Safety and Health (NIOSH). (2007). Elements of ergonomics programs: A primer based on workplace evaluations of musculoskeletal disorders. DHHS (NIOSH) Publication No. 2007-131.

[5] Hedge, A., & Powers, J. R. (Eds.). (2005). Workplace ergonomics: A comprehensive approach. CRC Press.

[6] Karwowski, W., & Marras, W. S. (2003). The occupational ergonomics handbook. CRC Press.

[7] Pheasant, S., & Haslegrave, C. M. (Eds.). (2006). Bodyspace: Anthropometry, ergonomics and the design of work (3rd ed.). CRC Press.

[8] Marras, W. S., & Karwowski, W. (Eds.). (2006). Fundamentals and assessment tools for occupational ergonomics. CRC Press.

[9] Occupational Safety and Health Administration (OSHA). (2000). Ergonomics program management guidelines for meatpacking plants. OSHA 3213-09R.

[10] European Agency for Safety and Health at Work. (2003). Risk assessment for repetitive movements and awkward postures. Retrieved from https://osha.europa.eu/en/publications/reports/302.