

Review Article

A Review on Ergonomic Studies for Different Industrial Setups

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Abstract

Awkward postures, improper rests, and repetitive forceful exertion are some key factors that may lead to work-related musculoskeletal disorders (WMSDs) such as fatigue, muscle imbalance, spinal dysfunction, and body pain etc. These are severe issues among the industrial workers that cause financial loss to the industry. As a scientific discipline, Ergonomics focuses on understanding the interactions between humans and their environment. Its goal is to enhance well-being, efficiency, and performance by designing products, systems, and work environments that align with human physical, cognitive, and psychological capabilities. It can significantly contribute to reduce work-related injuries, pain, and WMSD and enhance the safety and productivity. This paper introduces ergonomics and its importance, followed by ergonomic strategy implementation for improvement in working conditions of the workers, labours, and staff; and provides a review of some important past work conducted by various researchers on improving industry and/or workplace procedures and activities to obtain safety, productivity, and better health prospects. It aims to facilitate the scholars by providing knowledge on ergonomics and encourage them to establish the field further.

Keywords: Musculoskeletal disorders, Occupational health, RULA, REBA

Introduction

Occupational health and safety issues have always been given important consideration to minimize health risks, life hazards, and capital loss. These issues take place due to working for long duration in an awkward posture, inappropriate hand tool and workstation design, repetitive movements of body parts and forceful exertion further extends to work-related musculoskeletal disorders (WMSDs)^{1,2}. As a result, WMSDs cause reduction in workers' efficiency and a tremendous increase in down time that leads to financial loss. Without resolving WMSDs issues, it is difficult to achieve the best outputs. The study of a workplace and the equipment built for comfort, efficiency, safety, and productivity is known as ergonomics. By giving proper attention to ergonomics aspects in working posture, hand tool and workplace design, the efficiency of workers can be enhanced. The WMSDs related problems occur both in organized and unorganized sectors.

Introduction to Ergonomics

Ergonomics, which focuses on making sure employees are well fitted to their surroundings, information, jobs, and equipment, has long been concerned with the fit between people and their work^{3,4}. Instead of physically pushing a person's body to suit a task, ergonomic job design fits jobs to the worker. Numerous scientific fields have used ergonomics, including anthropometry, industrial hygiene, psychology, kinesiology, and physiology. It was first mentioned by a Polish academic in 1857, but it is now a major problem

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everywhere, particularly in developing nations like some of the African countries. To avoid or reduce accidents, ergonomics is relevant to many different sectors, including the construction industry. As a scientific discipline, Ergonomics focuses on understanding the interactions between humans and their environment⁵. Its goal is to enhance well-being, efficiency, and performance by designing products, systems, and environments that align with human physical, cognitive, and psychological capabilities. This review article provides a comprehensive overview of ergonomics, presents its important elements, and discusses significant developments in the field.

The origins of ergonomics can be traced back to ancient civilizations, where considerations of human comfort and efficiency influenced the design of tools, furniture, and workspaces⁶. The Industrial Revolution brought attention to the need for improved work conditions, leading to the emergence of ergonomic practices.

During the late 19th and early 20th centuries, several influential figures laid the foundation for modern ergonomics^{6,7}. World War II played a significant role in shaping ergonomics as a scientific discipline. Key societies and organizations dedicated to promoting ergonomics as a discipline were established. Ergonomics found applications in various industries, such as healthcare, transportation, and product design, leading to improved safety, comfort, and efficiency. The emergence of computer ergonomics and human-computer interaction further expanded the scope of ergonomics. Ergonomics has evolved significantly over time, influenced by various disciplines and societal needs. From its early origins to its current multidisciplinary nature, ergonomics continues to play a vital role in enhancing human well-being and performance. By understanding the history of ergonomics, researchers and practitioners can build upon past achievements and contribute to further advancements in the field.

The importance of ergonomics in various domains has been widely recognized. In the workplace, ergonomic design can significantly reduce the risk of musculoskeletal disorders, such as back pain and repetitive strain injuries, which are prevalent among office workers⁸. By considering factors like proper desk and chair height, keyboard and mouse placement, and lighting conditions, ergonomic interventions can enhance employee productivity, job satisfaction, and overall health. Moreover, ergonomics plays a crucial role in industries where physical demands are high, such as manufacturing and construction. By designing tools, equipment, and workstations that accommodate the human body's capabilities and limitations, ergonomic interventions can reduce the occurrence of work-related injuries and accidents. This, in turn, leads to improved worker well-being, reduced absenteeism, and increased productivity. The prime benefits of ergonomics are improved efficiency, productivity, safe work practices, increased employee engagement, and cost effectiveness etc.

Musculoskeletal Disorders and Other Health Issues

Musculoskeletal disorders (MSDs) in the workplace refer to conditions that affect the muscles, bones, tendons, ligaments, and other structures of the musculoskeletal system, which are caused or aggravated by work-related factors^{9,10}. These disorders can result from various occupational hazards and activities. Some common musculoskeletal disorders seen in the workplace include¹⁰:

1. ***Repetitive Strain Injuries (RSIs)***: RSIs occur due to repetitive motions or activities, such as typing, using a mouse, or assembly line work. Examples include carpal tunnel syndrome, tendonitis, and bursitis.
2. ***Back and Neck Pain***: Poor ergonomics, such as improper lifting techniques, prolonged sitting, or working in awkward postures, can contribute to back and neck pain. This can include conditions like herniated discs, muscle strains, or spinal disorders.
3. ***Shoulder and Upper Extremity Disorders***: Jobs that involve repetitive or overhead arm movements, such as painting or construction work, can lead to shoulder impingement syndrome, rotator cuff injuries, or frozen shoulder.
4. ***Hand-Arm Vibration Syndrome (HAVS)***: Workers who use vibrating tools or machinery, such as jackhammers or chainsaws, may develop HAVS, which can cause numbness, tingling, or pain in the hands and arms.
5. ***Work-Related Musculoskeletal Disorders (WMSDs)***: This term is used to describe a range of musculoskeletal disorders caused or aggravated by work-related factors. It can include conditions like tendinopathy, myofascial pain syndrome, or muscle strains.

Several factors contribute to the development of musculoskeletal disorders in the workplace, including repetitive motions, forceful exertions, awkward postures, vibration, and sustained or excessive pressure. Other factors include inadequate rest breaks, lack of ergonomic equipment or training, and high job demands. Preventing and managing musculoskeletal disorders in the workplace involves implementing ergonomic principles, such as proper workstation setup, using ergonomic tools and equipment, providing training on safe lifting and movement techniques, and encouraging regular breaks and stretching exercises. Employers should also conduct risk assessments, provide appropriate personal protective equipment, and promote a culture of safety and well-being.

The Essential Elements of Any Workplace's Ergonomic Program

The following steps are important to implement any ergonomic program at any industrial setup^{11,12}:

- Ergonomic Assessments
- Training and Education
- Ergonomic Equipment and Tools
- Workstation Design
- Work Breaks and Stretching Exercises

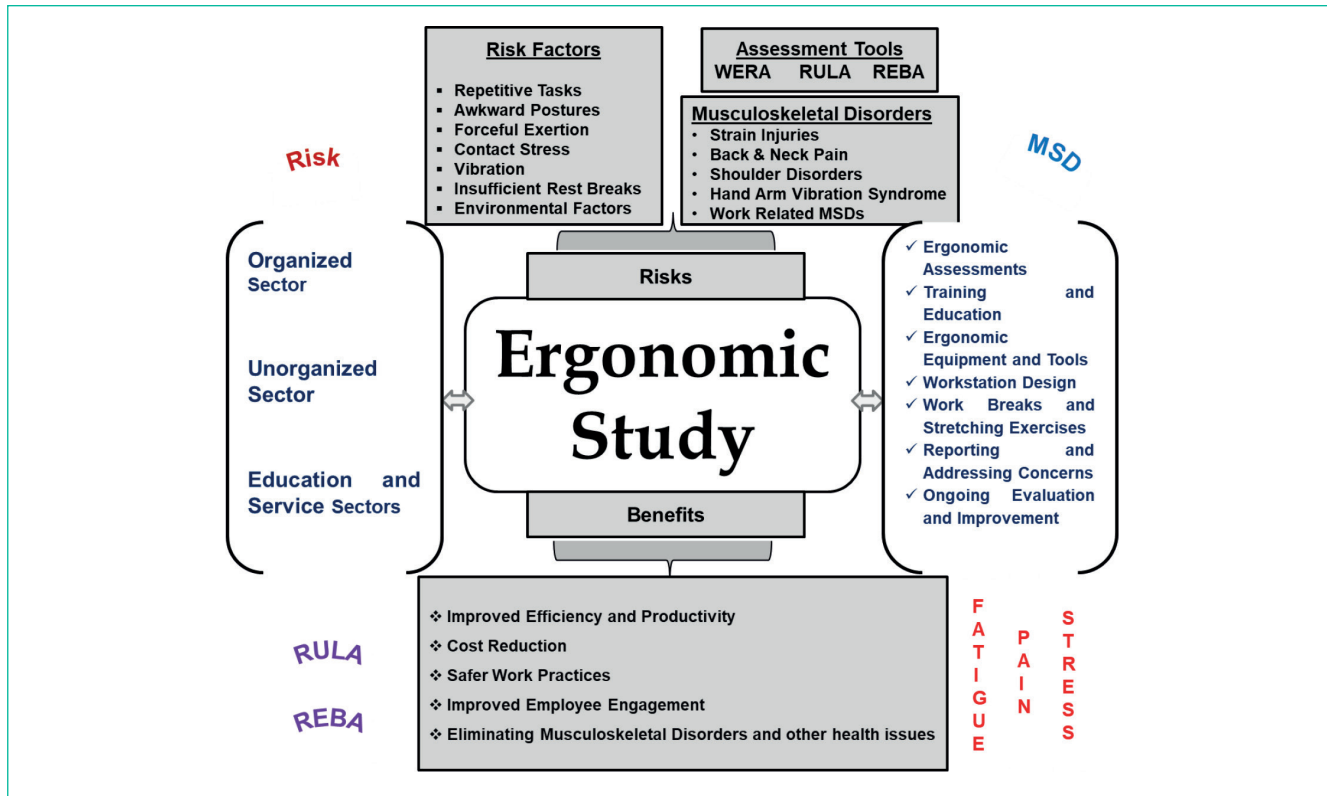


Figure 1. Insights on various important aspects of any ergonomic study.

- Reporting and Addressing Concerns
- Ongoing Evaluation and Improvement

By implementing these essential elements, workplaces can create a safer and more comfortable environment that promotes employee well-being and productivity. Figure 1 illustrates various important aspects of any ergonomics study.

The knowledge of ergonomics risk assessment (ERA) and risk factors is also very important. Ergonomic Risk Assessment is a program equips various tools, techniques, and processes for identification of risk and their mitigation, to make a safe, healthy, and productive workspace. Human wellbeing and high system performance are two essential inherent factors of ERA. Ergonomics risk factors refer to factors that can contribute to discomfort, injury, or strain on the body when performing tasks or using equipment. Some common ergonomics risk factors include^{12,13}:

Repetitive tasks:

Performing the same motion or task repeatedly can lead to muscle fatigue and strain.

Awkward postures:

Maintaining unnatural or uncomfortable body positions

for extended periods can put stress on muscles, joints, and other body structures.

Forceful exertions:

Applying excessive force or effort to perform tasks can increase the risk of musculoskeletal injuries.

Poor workstation setup:

Inadequate adjustment of chairs, desks, keyboards, monitors, and other equipment can lead to poor posture and discomfort.

Contact stress:

Pressure or compression on body parts, such as resting wrists on sharp edges or using tools with hard handles, can cause discomfort and injury.

Vibration:

Regular exposure to vibrating tools or equipment can cause syndrome related to body vibrations that consequently affect blood vessels, nerves, and muscles.

Insufficient rest breaks:

Not taking regular breaks or having inadequate recovery time can contribute to fatigue and increased risk of injury.

Environmental factors:

Factors such as extreme temperatures, poor lighting, and high noise levels can affect comfort and concentration, increasing the risk of errors and accidents.

It is important to identify and address these risk factors to create a safe and comfortable work environment that promotes productivity and well-being.

By observing, conducting interviews and discussions with the workers, and direct measurements, risks associated with any workspace can be assessed¹⁴. The process of risks assessment can commence with an investigation by collecting basic information, then urgency and severity of the risks are evaluated, that is followed by taking action to eliminate or mitigate those risks before a final evaluation is done. The following tools are utilized for risk assessment¹⁵:

Workplace Ergonomic Risk Assessment (WERA)

To investigate the physical factors that can be the probable cause of risks and WMSD, a simple method that involves observing the workplace as well as behaviour and posture of the workers and equipment setup and positions.

Rapid Entire Body Assessment (REBA)

Whole body posture and risks associated with the work, are evaluated using this method.

Rapid Upper Limb Assessment (RULA)

In this method, the risk of musculoskeletal loading within the upper limbs and neck, is calculated.

Ovako working posture analysis system (OWAS)

This method assesses loading of postures and working loads.

Review of Past Work

Ergonomics for Unorganized Sector

Applications of automation and technology is still at its initial stage for small scale industries and limited to large-scale production only. Unfortunately, very few researchers have conducted studies on ergonomic risk assessment and solving the WMSD issues, in the unorganized sector. Some of the important previous studies are reviewed and analyzed here as below and summarized in Table 1.

Physiological and musculoskeletal discomfort among the women workers in a brick manufacturing firm, were analysed in an ergonomic study¹⁶. A regular health check-up, nutritious diet, and exercises were recommended. Three workstation modifications have been suggested to reduce the WMSDs in a timber cutting sawmill, due to induced vibration and noise above the safe limit, and incorrect body postures, occurrence of severe health issues have also been reported¹⁷. In the movers and packers industry, an important case study was conducted in which rapid entire body assessment found bending and twisting of back, continuous hand raising for delivery, and heavy weight of parcels, as

risky factors¹⁸. Stone cutting, another important task in unorganized sector, also suffers WMSDs issues¹⁹. Ovako working posture analysis system (OWAS) has been found as an effective tool to evaluate postures of the workers involved in stone cutting activities. The study reported that working conditions like level of dust, temperature, sound, and visibility etc. also contribute towards health issues among the workers. Reorganization of workstations and redesign of working methods were the major recommendations. In an interesting study, RULA based new workstation design and list of recommendations helped extensively to reduce the workers' fatigue and posture related stress, in case of a hand-driven cotton spinning mill²⁰. Hand block textile printing industry is yet another extremely risky segment from the point of view of WMSD²¹. Hand block printing process was found the most unsafe among all other processes due to inefficient workstations design etc. It was reported that due to such issues, the workers leave such jobs early and it also affects health and productivity. A unique ergonomic study was conducted on private transport sector where bus drivers were interviewed and with the help of ergonomic work analysis, it was found that drivers suffered from knee and lower back problems²². A detailed recommendations in the form of improved workstation design, drivers' activities remapping, breaks and rests in between work, were made. Researchers from many countries investigated the ergonomic aspects in agriculture work²³⁻²⁵. Cultivating fruits and vegetables is indeed risky from ergonomic point of view and farmers undergo significant fatigue and other health problems while harvesting, pruning, and picking²³. Injuries during agricultural work are common and therefore use of gloves and hand tools can normally be employed to avoid and danger or hazard^{24,25}. RULA and REBA type tools are indeed important to evaluate risks and find corrective majors for farmers health and productivity. An important recent study examined the ergonomics perceptions about the workplace among shopping centres employees of different age, gender, and demography²⁶. It was reported that the employee working in shopping centres understand their work less risky from ergonomic point of view, may be due to their lack of awareness. WMSDs is also a crucial factor for restaurant workers²⁷. Study found that the workers who were above thirty years and not satisfied with their jobs, are sensitive towards WMSDs. In a survey conducted among building painters, it was highlighted that repetition of tasks, awkward postures, heavy pulling and lifting, and work height consequences were majorly responsible for MSDs²⁸.

Ergonomics for Organized Sector

Call Centre Workers who generally involve in continuous static work, also face MSDs issues due to no or very less movement²⁹. A study used rapid office strain assessment and found that all workers in call centre suffer from any MSDs or other health issue and require interventions related to working behavior, workstation design, and ergonomic

Sl/N	Type of organization	Ergonomics Tools Used	Recommendations	Reference
1	Brick manufacturing	RULA, REBA	Regular health check-up, nutritious diet, and exercises	16
2	Timber cutting sawmill	RULA, REBA	Modifications in workstations design	17
3	Movers and Packers	REBA	Employee rotation for workload variation	18
4	Stone cutting	OWAS	Reorganization of workstations and redesign of working methods	19
5	Cotton spinning mill	RULA	New design of workstations	20
6	Hand block textile printing	RULA, REBA	Implementation of health promotion programme	21
7	Private transport sector	EWS	Activities remapping, breaks and rests in between work	22
8	Agriculture/Farming	RULA, REBA	Use of gloves and hand tools	23-25
9	Shopping centre and restaurant	RULA, REBA	Rest, workers rotation, educating the workers	26,27
10	Painting	WERA	Ergonomic interventions, structure engineering control	28
11	Call centre	ROSA	Workstation redesign, change in working style/behaviour	29
12	Food industry	RULA, simulation	Improvement in working posture	30
13	Automotive industry	RULA, REBA, OWAS	Modifications in workstations equipment	31
14	Garment manufacturing industry	WERA	Worker friendly environment, improvement in workstation design	34,35
15	Metallurgy industry	Lean engineering, WERA	Ergonomically designed tools	37,38
16	Electronic industry	RULA, REBA	Rest, sufficient working area	39
17	Other facilities	Fuzzy logic, machine learning	Using Industry 4.0 tools and techniques	40-42

RULA: Rapid upper limb assessment. REBA: Rapid entire body assessment. OWAS: Ovako working posture analysis system. EWA: Ergonomic work analysis. WERA: Workplace ergonomic risk assessment. ROSA: rapid office strain assessment.

Table 1. Literature review summary on some important previous ergonomic studies.

factors. An interesting case study conducted to mitigate ergonomic risks in a food industry reveals the effectiveness of lean manufacturing techniques³⁰. With the help of RULA and simulation tools, improvement in working postures was recommended to reduce the MSD risks and lead time to enhance the overall productivity. In a chassis assembly line of automobile production, RULA, REBA, and OWAS based study concluded that more than 15% workers complaints were related to serious health risks issues and it was emphasized to design the ergonomic work chairs to facilitate the workers involved in assembly operations³¹. There are also some investigations conducted by researchers in past on interventions of intelligent techniques for ergonomic assessments, detecting MSDs and health issues, and designing workstations in automobile industry^{32,33}.

Ergonomic elements are also essential for garment manufacturing or clothing industry³⁴. An important study investigated the relationship between music and work performance³⁴. It was highlighted that the workers feel good

to work under the influence of ambient music and significant increase in the productivity was observed due to that. Saguyod et al. reported the importance of ergonomically designed workstation for cloth industry³⁵. They examined the tasks like knitting, cutting, and sewing; and found high risk of MSDs like limb disorders etc. They also reviewed the existing designs of workstations and reported some shortcomings and mismatch as the main reasons of the ergonomic issues. Ergonomic analysis using virtual tool, was recommended by Beuß et al. for aircraft manufacturing industry³⁶. They emphasized the role of simulation and its integration with sensors etc. to provide a remedy for ergonomic issue in aircraft manufacturing industry. Brito et al.³⁷ integrated lean manufacturing with ergonomics to tackle the challenges encountered in metallurgy industry. After eliminating wastes and improving the workstation design, more than 100% improvement in productivity was observed in various units of the industry. Another important work based on assessing the risk of MSDs in casting industry, identified that the

workers working under stress and fatigue, and reported that nutritious food supply and ergonomically design tools, can dominantly minimize the problems for highest safety and productivity³⁸. Yahya and Zahid³⁹ did postural analysis after conducting a survey among workers in an electronic parts manufacturing firm. Shoulders, lower backs, and wrists were highlighted as the major WMSD areas and pressing and unloading operations were the riskiest one. Limited work area, heavy equipment, and long-standing period were the main reasons identified.

Table 1 summarizes some of the important past research conducted on ergonomics studies in various industrial and commercial sectors.

To facilitate the attempts towards making workplace safe and comfortable, and for the better operational performance, some intelligent tools like fuzzy-based ergonomic value streaming mapping, fuzzy logic evaluation tool, machine learning, and neural network-based methods have been developed and used⁴⁰⁻⁴². Such attempts highlight the level of advancements being done in ergonomic field. Soft computing techniques like genetic algorithm and ant colony optimization have been found effective for optimizing the work scheduling activities in production lines to compliment ergonomics interventions in the sense that a successful distribution of assembly tasks to workstations in match with the technical skills and physical capabilities of the worker, was achieved^{43,44}. Deep neural network models were also used to monitor and assess awkward postures responsible for MSDs⁴⁵.

Ergonomics interventions have also been accepted as major contributing factors towards sustainability^{46,47}. Significant benefits such as plant safety, cost reduction, waste minimization, resolving workers' health issues, optimized workstation designs and improved workplace organization etc., of a successful ergonomic program strengthen the pillars i.e. economy, environment, and society, of sustainability.

Conclusion

In conclusion, ergonomics is of utmost importance in various workplace domains, including industries, service sectors, and unorganized areas. By considering the physical and cognitive needs of individuals, ergonomic design can enhance safety, comfort, and efficiency, leading to improved productivity, job satisfaction, and overall well-being. The review of past work indicates the necessity of identifying the ergonomic risks factors for finding proper solution to design safe and comfortable workplaces. Ergonomic tools like RULA, REBA, and OWAS etc. are the most extensively utilized techniques to study ergonomics for any industrial facility in order to find the root cause of issues that may lead to WMSDs and take corrective actions on time. It is also observed that modern methods like fuzzy, neural network, and machine learning can greatly help to secure safe, healthy, and productive workplaces. Finally,

it can be concluded that the successful implementation of ergonomics program contributes towards sustainable development.

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