Dimensions Identified for Physical Ergonomic Analysis in Manufacturing Industries: A Review

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Abstract

Productivity is a crucial factor in the manufacturing sector. However, exposure to poor ergonomic conditions can have a significant negative impact on productivity. Work-related injuries are a major issue in the active population of the manufacturing industry. This study examines the various ergonomic issues that could impact labour and result in illnesses, accidents, and musculoskeletal diseases, which reduce productivity. The aim is to reduce or eliminate work-related injuries and accidents altogether to boost productivity. This review pinpoints the variables crucial for physical ergonomic analysis in the manufacturing sector, such as job activities, the workplace, machine safety, work environment, and work organization. The inference is that identifying and addressing ergonomic issues is essential for improving productivity in the manufacturing industry. The study recommends creating surveys based on these aspects for workplace analysis in manufacturing industries.

Keywords: manufacturing industry, productivity, physical ergonomics

1 INTRODUCTION

The aim of ergonomics is to build a working system that enables people to work and live on it as effectively as possible by understanding human nature, talents, and limitations. As a result, it should be possible to complete the task's goals in a fast, safe, and enjoyable way. To meet the demands of the industry and minimize the number of musculoskeletal problems raised by working, ergonomic tool design is crucial. Ergonomics is the study of identifying workplace risks and creating mitigation plans for those risks. Applications could include anything from simple analysis to implementing cutting-edge technology and even expert systems. In the past, research has been done to improve work efficiency on the work systems of the pressing industry, the furniture industry, metalwork workstations, and public facilities. The core principle of this research is ergonomics.

Small and medium-sized businesses, commonly known as SMEs, are significantly contributing to the nation's overall economic growth, regardless of whether they're situated in urban or rural areas. This contribution can involve business activities. Our economy is shifting away from an industrial-based economy to one that is more knowledge-based for our country to achieve its goal for 2020. Manufacturers and industrial enterprises must be competitive as they take on new tasks in the industrial sector. Greater efficiency, less waste, and higher quality are crucial for market success.

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Small and medium-sized businesses, commonly known as SMEs, are significantly contributing to the nation's overall economic growth, regardless of whether they're situated in urban or rural areas. This contribution can involve business activities. Our economy is shifting away from an industrial-based economy to one that is more knowledge-based for our country to achieve its goal for 2020. Manufacturers and industrial enterprises must be competitive as they take on new tasks in the industrial sector. Greater efficiency, less waste, and higher quality are crucial for market success. (10) (12) Industries have long strived to make their processes more cost-effective and efficient. This led to the introduction of numerous disciplines, including Taylor's theory, TQM, Six Sigma, kaizen, and lean management. (21) However, most quality management strategies put more emphasis on strategies and technologies to obtain an advantage than on human factors, which have largely been ignored. The ergonomic approach must be considered for quality management disciplines to succeed, according to reports in the literature. (14) (17) (21) However, managers tend to ignore the affects of ergonomics to increase productivity, reduce MSDs, and cut costs in favor of considering it as a purely safety and health tool for preventing accidents and illnesses. This false belief stops enterprises from incorporating ergonomics into their manufacturing processes or procedures for quality control. (3) Even though most businesses have lately adopted production system techniques as their primary methods of operation, ergonomics has historically been more valued as a means of preventing musculoskeletal diseases (MSDs) than as a tool for improving quality.

Four categories can be used to identify the main contributing components for ergonomics: individual factors, environmental factors, physical factors, and organizational problems. The need for companies and employees to take more initiative in addressing problems related to workplace postures is growing. When employees are exposed to additional risk factors at the same time, the likelihood of accidents related to their work increases. Therefore, it is crucial to identify all relevant components to lower the risk of potential ergonomic issues. This article's primary objective is to present empirical evidence that supports the implementation of ergonomics in manufacturing industries as the main business objective doing so would have beneficial impacts on both productivity by increasing the production process quality by reducing error and injury prevention for safety and health.

2 CONCEPTUAL FRAMEWORK FOR PHYSICAL ERGONOMIC ANALYSIS IN MANUFACTURING INDUSTRIES

In Fig 1, the conceptual framework can be seen. This serves as an example of the consequences of a poor ergonomic approach in a manufacturing system. According to the ergonomic approach, work factors such as physical ergonomics, cognitive factors, and organizational ergonomics have an impact on both employee well-being and production levels. Finally, brand image reduction, difficulties in hiring new staff, and price would all influence business and marketing.

The effect of the ergonomic approach on productivity and general well-being of people was not investigated in this review. However, there are significant connections between these concepts, as seen in Figure 1.

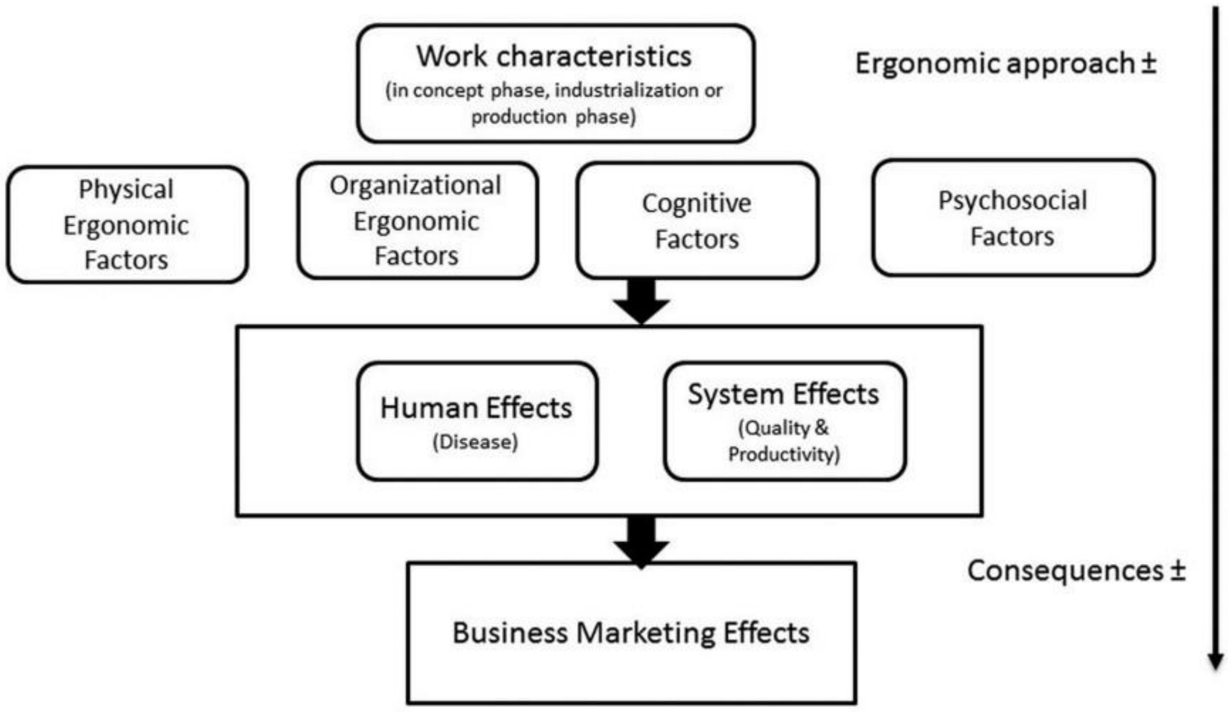

FIGURE 1

The conceptual framework depicts the negative effects of a subpar ergonomic strategy.

3 MATERIALS AND METHODS

The use of peer-reviewed publications for inclusion was decided upon, also search techniques for discovering peer reviews, the selection of peer reviews, and the assessment of peer reviews included in the research. From 1990 through March 2021, academic databases including Google Scholar, Springer, Web of Knowledge, and Science Directs were searched. Also, a number of peer-reviewed publications were particularly searched, including A Journal of Prevention, Evaluation & Rehabilitation, Human Factors, Ergonomics in Manufacturing & Service Industries, and Applied Ergonomics. We used a different set of search terms and strategies for each database in order to get the best results and prevent missing literature.

The key concepts within the issue were first identified to formulate the search strategy. Then, the search terms that would best explain those concepts were chosen, and their synonyms were taken. Finally, we had our search plan ready. Our queries were made up of many sentences that were combined using various Boolean operators, including parentheses, wildcards, "AND" and "OR." We used phrases that contained word combinations that were precisely repeated in the search documents. We applied two or three notions that each had six or seven words in our questions. We divided all the keywords into four groups: manufacturing and organizational systems, quality and system effects, ergonomics, and occupational health.

Occupational ergonomics, human factors, human-factor engineering, ergonomic solution, ergonomics integration, work* (s, ing, place) condition, workstation design(ing), participatory ergonomics, and occupational health & ergonomics were among the 20 terms that made up the first set of phrases/words related to ergonomics. Twenty-five expressions made up the second group of keywords, including Quality* (y, ies), Service* (s, ing) Quality, Improv* (ed, ing) Quality, Continu *(e, ing) Improv *(ement, ing), Rejection Rate, and Human Error. The next category included Production Process, Manual Assembly, Automotive Industry, Assembl* (y, ing) Plant, Production System, and Manual Assembly. Phrases relating to cost-effectiveness, cost benefits, and cost-savings were included in the last group of phrases. The Boolean operators were used to combine these phrases multiple times and in varied ways. We also verified the reference lists of the relevant papers to ensure sure that all peer-reviewed articles in this domain were examined. More than 260 results were available for review in all sources and journals searched. We looked over the article titles and abstracts that were found. After reading the complete articles of various publications and scanning respective abstracts, some articles were excluded. Eventually, the peer-reviewed studies conducted in industrial environments, particularly the global automobile industry, made up the publications we included in our review. Medical facilities and other service sectors, including hospitals and clinics, were not included in the studies. Interventions in occupational health and safety were not included unless there was a clear ergonomics component. Research focusing solely on how ergonomic interventions impact workers or productivity was ignored. The included publications were reviewed, and details about the objectives, interventions, research approach, demographics, industries and workplaces, confounding factors, outcomes, outcomes, and conclusion were collected.

4 RESULT

Several publications show the impact of the ergonomics approach on workers and the manufacturing industry found after a comprehensive investigation of the databases mentioned. After a review of the publications discovered and a primary screening of the whole articles, 29 papers were eventually selected for inclusion in our study. The 29 suitable studies were then subjected to a methodological quality assessment, after which 4 were excluded. (13)(Dury, 2003)(Inma et al., 2003) (13) owing to a conflict with this review. Table 1 includes details 14 major studies of the total studies conducted as well as the primary results and features of the 25 papers that were ultimately included. Research look at how cognitive and psychological aspects, together with organizational, physical, and ergonomic features, affect product quality. The publications under consideration largely illustrated how the ergonomic approach's components affected technology and humans.

4.1 EFFECTS OF PHYSICAL ERGONOMICS IN MANUFACTURING INDUSTRIES

The correlation between physical ergonomic risks, injuries and productivity was shown in twelve studies. In general, the included investigation shows a significant correlation between high ergonomic workload and product errors. Case studies were undertaken in the Volvo manufacturing industry by (20) covering the processes used in car engineering, the location of the car assembly plant, and quality monitoring of finished vehicles sold on the market. We observed a substantial correlation between poor physical ergonomics, injuries, and quality problems in all three phases. Ergonomic issues accounted for 23.5% of the 352 quality issues that were recorded during the manufacturing engineering process for three new car models. 55 assembly tasks for 24443 automobiles were examined in the production line.

Quality mistakes were 39% for assembly jobs with a high physical ergonomic workload (red tasks), 48% for those with a medium physical ergonomic workload (yellow tasks), and 13% for those with a low physical ergonomic workload (green tasks). Following 216 completed autos for eight weeks after market sales revealed that only one error was associated with green tasks, while 27% of errors were associated with yellow tasks and 70% with red activities.

Following 216 completed autos for eight weeks after market sales revealed that only one error was associated with green tasks, while 27% of errors were associated with yellow tasks and 70% with red activities. Compared to red assignments, yellow tasks were more likely to result in plant-quality mistakes. Other ergonomic issues (organizational, cognitive, and psychological) as well as incorrect task classifications as red or yellow are potential causes (observer effects). (20) The authors came to the conclusion that high-risk duties, such as working below, behind, or at a distance, keeping uncomfortable postures, and using aggressive operations, resulted in more mistakes. Sharp edges, static jobs, and material handling, however, all showed perfect reliability. Just one task, classified as yellow in another similar study by Falck was responsible for 92% of errors found in the market. Red tasks had an error rate of 7.4%, whereas green tasks had an error rate of 0.65%. 47 assembly tasks for 47,061 cars were examined, and the failure rate for the red tasks was 55.1%, the yellow tasks were 37.8%, and the green tasks were 7.1%. (4) (10) In both trials, there were fewer mistakes on green tasks than on yellow and red ones, which supported their theory. Both of the studies into the mistake rates for yellow and red jobs, however, revealed the gap. (4) (20)

In their second investigation, Falck et al. ignored frequent physical ergonomic concerns that led to quality problems. The findings indicated that the number of errors for the high load of work activities was probably affected by the kind of physical ergonomic risks as well as other ergonomic approach factors. Similar case studies by Almgren et al., (2012) in the production of Volvo trucks revealed that red assembly activities on average produced 12.68 errors per minute whereas green tasks produced 4.79 errors per minute. Tasks were divided into two groups in this study, with yellow activities being disregarded or split into green or red tasks. In addition, green activities were distinguished from red tasks in a different way. Therefore, it's possible that some tasks were incorrectly categorized (15). In studies by Falck et al., (11) assembly operators (rather than ergonomists) recognized ergonomic high-risk jobs in the study by Almgren and Schaurig (15) Therefore, the ergonomic evaluation's validity might have been in question. This is likely why red tasks in this study had a less impact on quality errors (2.5 times fewer than green tasks) than they did in Falck's study (11); (7.5 times more than green tasks). Regarding high-risk assignments, Almgren and Schaurig (15) provided examples of typical quality mistakes. Physical and ergonomic risk factors, that had led to major failures, were disregarded. In the study by Falck et al., the most typical quality mistakes committed with high-risk jobs were.

In a study conducted by Fritzsche, Schmauder, Wegge, Kliegel, and Schmidt (19), 623 assemblers in the German automotive sector were included. The ergonomic workload was evaluated using a customized version of the Automotive Assembly Worksheet approach. The Reason approach (22) was used to classify a total of 22821 faults into 3 categories: 54% slips (task performance), 35% memory failures, and 10% mistakes. The findings revealed that for the highest physical workloads, mistakes increased by 80%. Physical demands increased the chance of slips and lapses by 3.66 and 2.44, respectively, but there was no correlation with errors. Age and diversity were considered as confounding factors in this study, and common mistakes were categorized (11)). Execution of task failures was the most often discovered mistake, which was similar to the findings of Falck et al. (20) and Almgren and Schaurig (15). The effects of various physical workloads, psychosocial issues, and organizational factors were not examined by Fritzsche et al. (19) According to Axelsson, 18 tasks with high ergonomic risks were responsible for 82% of operator errors. Out of the 18 tasks, 15 of them underwent intervention, which resulted in a 3.9% decrease in rejection and failure rates (Axelsson). Gonzalez et al. (Beatriz A. Gonzalez, Belarmino Adenso-Dıaz, 2003) demonstrated that the physical ergonomic intervention boosted product quality by 2% and considerably decreased the need for part reprocessing. Despite a reduction in a material loss to under 45%, the number of rejected components did not change statistically because of the intervention. The likely explanation is that, even though task demands remained high in nature, physical risk factors were eliminated by implementing facilities such as lifting equipment and instructions for adopting healthy postures. The other aspects of the ergonomic approach, such as design and production adjustments, were not examined in this intervention study.

Uncomfortable postures can lead to a range of quality issues, such as leaks, loose clips, ignored screws, and uneven placements, as shown by Neubert, Bruder, and Toledo. Hence a model that considered physical ergonomics and comprised the production level (reworking, and scrap), organizational levels (productivity and quality), and operator level was proposed (performance and health). Although not having their model experimentally tested, the authors predicted that, depending on the industry, ergonomics may result in savings of 25%. The impact of uncomfortable postures on quality faults or cost savings were not mentioned in Neubert's study. (5).

In an experimental study, Das, Shikdr, and Winters (9) recommended ergonomic treatments for a drill press operation, including appropriate seats and tables, design and layout adjustments, and thorough training techniques (using MTM analysis). Then, a two-group experimental inquiry was constructed to evaluate operator contentment, quality, and productivity (number of holes produced). Quality significantly improved (by 52%), and productivity rose (24%). (9). However, because the participants in this study were not professional operators and it was conducted in a lab environment, there are several confounding variables that could have influenced the findings. These include workplace conditions as well as cognitive and psychosocial variables that are present in actual workplaces.

TABLE 1. Summary of Research Focus on Physical Ergonomics

Authors	Workplace	Variables	Description of Study
Almgren & Schaurig (2012)	Assembly line at Volvo truck	Ergonomic workload and product quality	These tasks' Quils system quality flaws were compiled, the outcomes were compared, and the red and green tasks that satisfied the requirements were picked.
Axelsson (2000)	Assembly plant	Work postures and quality	RULA reviewed 40 tasks, and it determined that 17 high-risk tasks were responsible for 80% of the quality issues. After 14 tasks were ergonomically enhanced, the RULA and other assessment were carried out.

Ayub & Shah, (2018)	Shoe and garment manufacturing workers	Risks for WMSDs	The more pain experienced workers reported in various body areas, the higher the likelihood that they have WMSDs. According to the Nordic questionnaire, 79% of the sample's workers reported experiencing pain in various bodily regions; 86% of these workers reported experiencing pain in the upper body, and 14% reported experiencing pain in the lower body, which was corroborated by the QEC and RULA score sheet. (Ayub & Shah, 2018)
Das et al. (2007)	Simulated drill press operations	Ergonomic, work design and modifications, task performance (quantity and quality of products), and worker satisfaction	In an intervention research, existing workstations, machinery, and manufacturing activities were all evaluated for ergonomics. The next step was redesigning the workstation and training the operator. Two scenarios were used to compare the variables.
Del Fabbro & Santarossa (2016)	Home appliances industry	Ergonomic intervention	An inventive method of analysis will provide quick comprehension of any occupational physical condition and superior solution selection for both random and mass working operations. (Del Fabbro & Santarossa, 2016)
Erdinc & Vayay (2008)	Sewing machine task	Ergonomic risk factors and quality	A three-phase intervention research that involved planning, evaluating, and implementing was carried out. After doing an ergonomic assessment, ergonomic training and workstation modification were implemented.
Falck et al. (2014)	Manufacture assembly of car plant	Ergonomics, quality errors, costs	47 assembly activities were divided into three ergonomic workload categories: high (16), moderate (18), and low. Then the manual assembly error rates for 47,061 automobiles were examined.
Falck et al. (2010)	Automobile company in Sweden	Quality defects, ergonomics, and costs in 3 processes, including manufacturing engineering, assembly process, and factory complete cars	Three new automotive projects were selected when the production engineering study first began. Quality and ergonomic workload for assembly items were compared. The manufacture of 55 assembly pieces for 24,443 autos over 8 weeks was then examined. Finally, over the course of 17 weeks in market, quality issues for 55 chosen assembly pieces for finished autos were gathered.

Fritzsche et al. (2014)	Large automotive industry in Germany	Ergonomics, absenteeism, and quality performances	55 automotive assembly teams (n = 624) participated in a study over a year to examine the impact of ergonomics, and age on absenteeism and performance.
Gonza´ lez et al. (2003)	Metal Manufacturing factory	Ergonomics, production quality	The folding industry was chosen, and the RULA approach was used to discover ergonomic concerns after direct observation to identify quality records. Interventions were carried out, and a new methodology was established based on the RULA score.
Il ardi (2012)	Fish industry	Ergonomics, productivity, and quality	The Nordic Questionnaire and OCRA methods were used to identify ergonomically risky tasks. Information was gathered about the deboned meat’s quality.
Murcia et al., (2021)	Human Operators in Industry	Health-Related Parameters for Evaluation	The study is being done on long-term physical strain, primarily using physical and simulation techniques to emphasize physical constraints at work.(Murcia et al., 2021)
Neubert et al. (2012)	Volkswagen automotive industry	Describing good impact of the ergonomics in reducing losses	Ergonomic workplace design affects numerous production, personnel, and business level indicators of the organization to produce efficiency.
Yeow & Nath Sen (2006)	Printed circuit assembly factory	Ergonomic intervention, productivity, and costs	To discover ergonomic risks and reasons for low productivity and quality, a questionnaire was filled out. Direct observation is then conducted for each cause with a higher rating. Finally, root cause error intervention was carried out. (Yeow & Nath Sen, 2006)

5 CONCLUSION

The purpose of this review was to investigate the physical ergonomics approach's effects on manufacturing, especially in the automotive industry. There were 25 empirical investigations in total. The studies under consideration offered proof of how inadequate ergonomic practices affect quality errors, particularly in the automotive industry. However, there is still no evidence of how various ergonomic dimensions physical, cognitive, and organizational interact with one another or how they affect quality. There is currently a dearth of data on how cognitive ergonomics and psychosocial factors affect quality. Manufacturing managers still view ergonomics as a tool for preventing illness and injury rather than to cut costs and waste, according to surveys of these managers.

The study reviewed several publications to understand how ergonomic aspects affect product quality. Out of 29 selected studies, 4 were excluded, and the remaining 25 were assessed for their methodological quality. The investigation showed a strong correlation between high ergonomic workload and product errors in the manufacturing industry. The study analyzed the manufacturing process and found that poor physical ergonomics contributed to 23.5% of quality issues during production. The study also revealed that tasks with a high physical ergonomic workload were more likely to result in errors than tasks with a low physical ergonomic workload. The findings suggest that tasks that require working below, behind, or at a distance, keeping uncomfortable postures, and using aggressive operations result in more errors. The study also identifies the potential causes of ergonomic issues, including cognitive, psychological, and organizational factors. However, the validity of the ergonomic evaluation was in question in some cases, as the classification of tasks as red, yellow, or green was inconsistent between different studies. The study concludes that physical ergonomics plays a significant role in determining product quality in the manufacturing industry.

The physical ergonomics of the workplace have a significant impact on the health, satisfaction, and productivity of workers. Using reliable questionnaires is one method for assessing the general state of workplace environments. Most of the literature studied concentrates on physical ergonomic problems in manufacturing industries which involves postures, manual tasks, and repetitive movements. Converting the Ergonomic Checklist into 5-point scale Questionnaires would help in getting the required data directly from the worker. Major dimensions Identified for Physical Ergonomic analysis based on literature job task, workplace, material handling & tool, machine safety & facilities, and work environment (ventilation, temperature, lighting, noise & hazardous substance).

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