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ENHANCING WORKPLACE EFFICIENCY AND EMPLOYEE WELL-BEING THROUGH ERGONOMICS, 5S, AND KAIZEN IN MANUFACTURING

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ABSTRACT
Musculoskeletal disorders (MSDs) pose a significant threat to worker well-being and productivity in manufacturing environmnet. While Lean manufacturing focuses on waste elimination, Ergonomics stress on efficient designing work place. The integration of Lean manufacturing with ergonomics to address MSDs and enhance productivity remains under explored.The present research work is in the form of a case study which investigates the advantages of an integrated operations management approach combining ergonomics and Lean tools in stamping division of a manufacturing company in India. Ergonomic assessments were conducted using the Nordic questionnaire and Rapid Upper Limb Assessment (RULA), while Lean tools such as 5S and Kaizen were implemented to reduce waste.The integrated approach successfully eliminated or reduced non-value-added movements, leading to a more organized and ergonomically sound workplace. This resulted in significant improvements in worker safety, health and productivity.The study demonstrates the synergistic benefits of integrating ergonomics and Lean manufacturing. It calls for broader adoption of this approach to enhance both worker well-being and operational performance in manufacturing settings.
Keywords: Ergonomics, Lean manufacturing, Musculoskeletal disorders(MSD), Productivity, Workplace safety.

I . Introduction
Modern manufacturing organizations must consistently adapt to the changes to improve product value in today's competitive business environment.Implementing value-added processes is a significant approach for achieving adaptation and improvement.Hence, implementing Lean manufacturing principles offers a structured approach to maximize resource utilization and minimize waste, thereby maximizing the product value. So Lean manufacturing helps organizations adapt to rapidly changing business environments [1]. Lean manufacturing principles, rooted in the Toyota Production System, enables organizations to streamline production flows, reduce lead times, and improve product quality [2].
Manufacturing industries often continue to rely heavily on manual labor, which exposes workers to the risk of developing musculoskeletal disorders (MSDs) due to repetitive motions, uncomfortable postures, and prolonged exertion [3].These injuries not only negatively affect an individual's health and on the quality of life, but also contribute to increased absenteeism and reduced productivity, resulting in substantial financial losses for companies on an annual basis, amounting to billions of dollars [4].
Even though lean manufacturing has proven to be an efficient approach for increasing efficiency and performance across a wide range of sectors.However, lean processes can lead to highly repetitive tasks, depriving employees of essential rest periods. The repetition of tasks can strain employees, subjecting them to stressful postures and excessive exertion throughout the workday [5]. This shows the benefit of integrating ergonomic principles into Lean manufacturing processes.

Ergonomics, the science of designing work place and tasks to fit the skills of the workforce, plays a pivotal role in ensuring worker safety, comfort, and productivity [6]. In manufacturing industries, where manual labor is prevalent, ergonomic interventions are necessary to address musculoskeletal disorders, fatigue, and injury risks among workers [7].

Several earlier studies have reported a significant negative impact of neglecting ergonomics on staff turnover , decreasing the morale and ultimately reducing the overall productivity
[8]. Research has demonstrated the effectiveness of ergonomic interventions in reducing injury and preventing work-related physical disabilities among assembly line workers.For example,a study in the Textile Industry shown how ergonomic redesign can reduce musculoskeletal discomfort and improve performance among industrial workers [9]. Meanwhile, a study conducted in foundry industries of India has proved that an ergonomic workstation design may alleviate ergonomics stresses and improve worker performance as it can prevent work-related MSDs or pain [10].

Integration of Lean Manufacturing with Ergonomics Together, there are a range of top to down to bottom advantages the implementation can offer for all the manufacturing industries. This enables companies to synchronize operational efficiency and quality with human factors, creating an efficient and flexible lean process [11].

As an example, a case study found that lean manufacturing combined with ergonomics intervention resulted in faster production cycles and subsequent improvements in ergonomic conditions and better worker well-being amongst manufacturing firms in Portugal [12]. Further, a study in Malaysian manufacturing environments demonstrated that lean combined with ergonomic principles resulted in productivity improvement together with lessening of ergonomic risks [13].

This research is motivated by the desire to explore and confirm any synergies between ergonomics and lean manufacturing in a real industrial environment. A case study in India was conducted specifically to evaluate the impact of an integrated operations management on MSD risk and productivity at a stamping division of a manufacturing company. The objectives of the study will be:

- **Quantify Ergonomic Hazards:**Apply established assessment tools like Nordic questionnaire and Rapid Upper Limb Assessment (RULA) to identify and rate the severity of ergonomic risks in your manufacturing.
- **Use Combined Applications**: Find out ways in which ergonomic interventions can be used with Lean manufacturing principles, including 5S and Kaizen, to improve productivity.
- **Evaluate Impact:**Evaluate the influence of the integrated approach on worker safety, health and efficiency leading to improved productivity.

This research seeks to prove that investing in both worker well being and operational efficiency is not only feasible by means of an integrated approach, but also mutually beneficial. The results of this research could affect wider and more improved implementation of integrated operations management practices in manufacturing. It aims to establish a proof-of-concept of holistic approach where the value of well-being and operational efficiency are blended, which leads to achieving a better safety, healthier and more productive manufacturing surroundings.

II. Methodology

To make the current research work more feasible, a real life example was considered form a SME form pune, India. During the preliminary discussion with the management of this organization, it was found that. Its stamping division was facing significant ergonomic and operational challenges. This work takes a comprehensive approach that integrates ergonomic assessments and lean tools to overcome the existing challenges. The focus is on employee safety, comfort by reducing awkward postures and repetitive tasks, and improving productivity by minimizing operational inefficiencies such as scrap collection and tool clamping. Thirty-eight employees (male and female) with their consent and at least 2 years of work experience were purposively selected for the study to ensure that

the different roles and responsibilities were represented considering the time and financial constraints of the study.

The ergonomic assessments began with primary data collection by observing workers performing various tasks such as lifting, handling scrap, and operating machinery. Photos and videos were taken to document posture and movements. The Nordic Musculoskeletal Questionnaire (NMQ) was used to collect data on complaints and musculoskeletal problems reported by employees [14][15]. The outcome of NMQ assisted in indentifying the postures across various process that required ergonomic intervention. For these postures, Rapid Upper Limb Assessment (RULA) scores were calculated to identify high-risk activities requiring intervention [16][17]. For example, tasks with an RULA score of 7 were flagged for immediate action.

Based on this information, digital models of the workplace were created in Catia V5 software to simulate and evaluate the postures [18][19]. Based on these results, measures were taken, such as the introduction of a platform to reduce bending when lifting. This measure significantly improved the ergonomics, of the posture and reduced the RULA scores from 7 (high risk) to 3 (medium risk).

After the posture analysis, all those work processes where modifications were carried out are considered and 5S method was introduced to streamline and improve the organization of the work area. First, an inspection was carried out to identify unnecessary tools, materials and equipment cluttering the work area. These were sorted and removed to improve space efficiency (Sort). Storage areas were then reorganized and labeled zones were created to facilitate access to tools and materials to reduce search times (Set in Order). A daily cleaning schedule was created to maintain a hygienic and organized environment (Shine). Standard operating procedures (SOPs) were documented to ensure the sustainability of improvements (Standardize), and an incentive system was introduced to motivate employees to adhere to these practices (Sustain) [20][21].

Two major kaizen initiatives were implemented to eliminate certain operational inefficiencies [22][23]. The first focused on optimizing scrap collection. Previously, scrap scattered around the workshop posed a safety risk and slowed down operations. Special trolleys for scrap collection were developed and introduced, and employees were trained in the use of these trolleys. This led to a 20% reduction in handling time and significant improvements in workplace safety. The second initiative concerned the clamping of tools, which was manual and time-consuming. Screw jacks were installed at each workstation to enable faster and safer tool clamping. This measure halved the clamping time, saving 5.4 hours per month and increasing production efficiency.

Both quantitative and qualitative analyses were carried out to test the effectiveness of these interventions. An analysis of the responses to the Nordic questionnaires showed that workers' musculoskeletal complaints decreased. Productivity metrics, including time savings in tool clamping and scrap handling, Showed significant operational improvements. In addition, post-implementation surveys and interviews revealed higher employee satisfaction and a perceived improvement in safety.

III. Results

As mentioned earlier,the study comprised of 38 participants, ranging in age from 19 to 45 years. According to the Body Mass Index (BMI), 61% of employees have normal weight, while only 21% were overweight and 18% were under weight. The study was conducted during the day shift. Table 1 shows the details of the demographic figures of workers.

Table 1: Demographic figure of workers (n=38)

Sl.No.	Particulars	Minimum	Maximum	Mean (SD)
1	Age (Years)	19	45	27.32(6.63)
2	Height (Meters)	1.32	1.82	1.56(0.11)
3	Weight (Kg)	35	70	53(10.20)
4	Experience (Years)	2	20	6.5(5.0)
5	BMI (Kg/M^2)	14.34	27.58	21.67(3.21)

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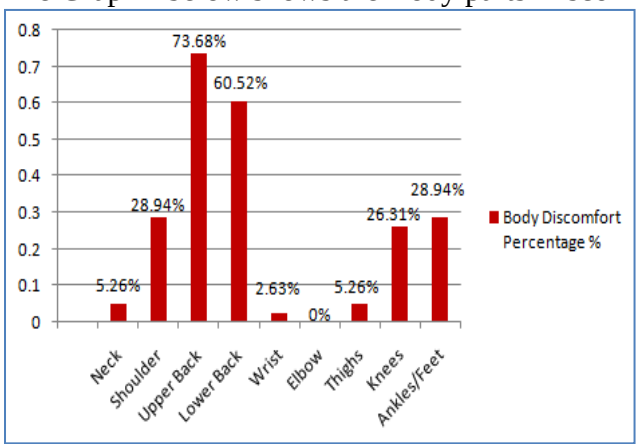
To find out the occurrence of MSDs, Nordic musculoskeletal questionnaire was used. The occurrence of Work-Related MSDs in various body parts of workers is presented in Table 2.The MSD questionnaire show that more than 74% of the workers were suffering from upper back discomfort and while 60% reported lower back discomfort.

Table 2: Nordic musculoskeletal Questionnaire Findings

Body Parts	Number of workers (n=38)	Percentage %
Neck	2	5.26
Shoulder	11	28.94
Upper Back	28	73.68
Lower Back	23	60.52
Wrist	1	2.63
Elbow	0	0
Thighs	2	5.26
Knees	10	26.31
Ankles/Feet	11	28.94

The Graph-1below shows the Body parts Discomfort of workers in Percentage .



Graph 1: Body Discomfort in Percentage in various parts of body

As stated, the hazards associated with the working postures were determined using the RULA assessment method. Forty postures were captured, and Photographs taken using a high quality phone camera were examined. The risk score was calculated using the RULA assessment and scoring sheet .Table 3 displays the results of the analysis.

Table 3: Distribution of RULA score among workers

RULA Level	RULA Score	Action	Number of Postures(N=40)	Percentage %
0	1-2	Acceptable posture	6	15
1	3-4	Further Investigation, Change may be needed	24	60
2	5-6	Further Investigation change soon	08	20
3	7	Investigation and Implement change	02	05

The below Graph-2 shows the RULA Scores .

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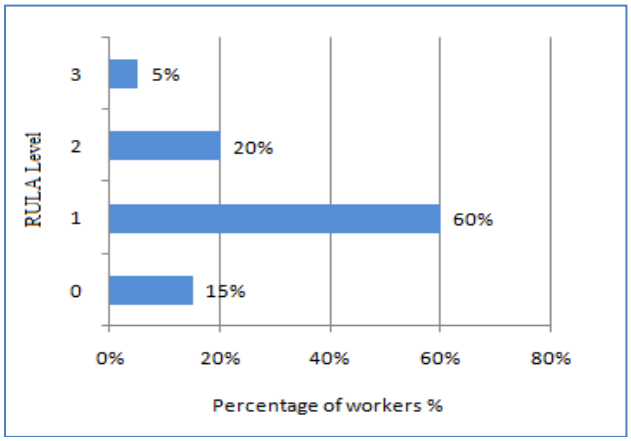


Graph 2: Categorization under RULA Level

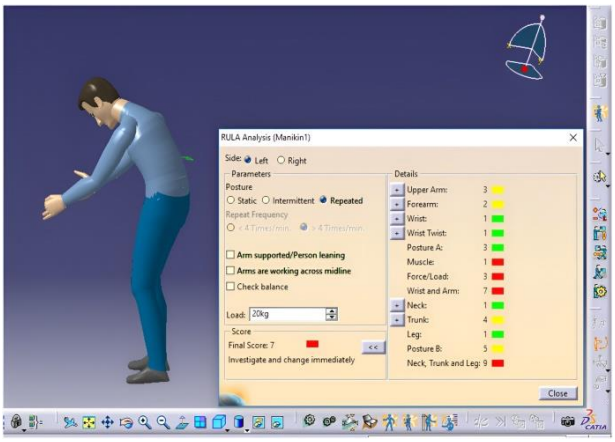
A poor working posture of a worker while performing tasks on the shop floor is depicted in Figure 1(a), which corresponds to a worker lifting a 50 kg load bag. The chosen posture increases the risk of developing musculoskeletal disorders (MSD). Due to the worker's requirement to bend their backs and the excessive use of back muscles, an awkward body posture might be observed. Incorrect lifting methods or overstressing inadequately conditioned lower back muscles may result in ligament sprains or muscle strains [24].

Catia V5 software includes human modeling and ergonomics analysis capabilities. The software has four modules: Human Builder, Human Activity Analysis, Human Posture Analysis, and Human Measurement Editor. These modules allow users to create and customize human models, analyze their postures and movements, and identify potential ergonomic risks. RULA is one of tool which is supported by this module [25].

The depicted work posture converted in Catia V5 software for Rapid Upper Limb Analysis seen in Figure 1.b shows a worker lifting a load—awkward body postures during work and repetitive heavy lifting present major occupational concerns. The RULA score is notably high, reaching 7, which indicates a high risk & necessitates immediate postural adjustment. Improving the upper arm, neck, and trunk posture is recommended to reduce the RULA score. Engineering interventions were suggested for this activity by creating a platform at an approximate height of about 60 cm. The platform can store the bags brought from the supplier.

In the new improved method, a trial was conducted by temporarily creating a platform and instructing operators to pick bags without excessive bending. The new posture demonstrated in Figure 1. c minimizes strain on the lower back and upper arms, reducing the RULA score to a medium risk level of 3.

1.(a)



1.(b)

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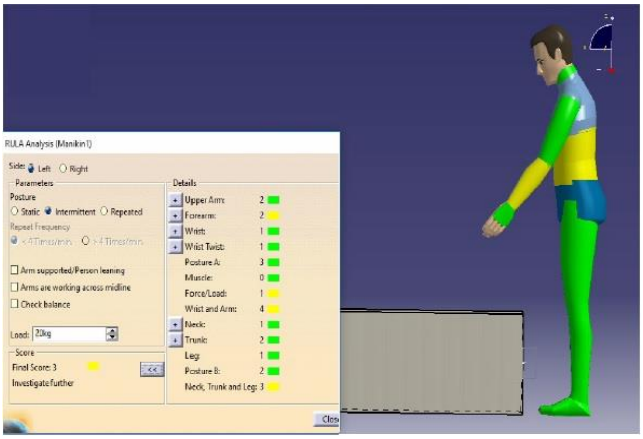

1.(c)

Figure 1. a: Postures of worker involved in lifting activity, b: The work posture of the worker was modeled using Catia V5, c: The final score of the posture by RULA analysis is '3' after suggested intervention.

5S Implementation:-

Various sections within the stamping unit were designated for tools storage, utility carts, excess inventory, and workers belongings. This prompted the question of how to effectively organize these different sections. The solution was to initiate a 5S event. The individual responsible for the process was assigned to apply the 5S methodology across the entire unit. Embracing this challenge required thoughtful consideration of factors including workers morale, search times, and the effective communication of upcoming changes [26][27]. As a result, the goals for the 5S event were set as follows:

- Simplifying the work environment.
- Achieving effective workplace organization.
- Reducing waste while enhancing safety and quality.
- Facilitating the improvement of efficiency and productivity.

S1 Seiri (sort):

Excess equipment, tools, and furniture are retained for depreciation or potential clearance, while surplus materials return to suppliers seamlessly.Any waste discovered is promptly and responsibly disposed of or recycled. Items identified as unnecessary undergo a red labeling process, clearly indicating their lack of necessity. Employing a systematic approach, we have diligently sorted and eliminated all useless items. Pictures in Figure 2. are taken to distinguish the before and after condition of a storage room, thereby highlighting the significance of this process.

Figure 2 : Sorting Before and After

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S2 Seiton (set in order):

The subsequent action involves assigning a specific location for all equipment, machines, tools, and raw materials, consequently minimizing the time required for retrieval.the tools and equipments were not placed in well defined area on the shop floor. To reduce wastage of time in searching of tools and equipments we assigned well defined area on the shop floor. Figure 3. shows the before and after conditions of the shop floor, illustrating how tools and equipment were Set in Order to enhance workspace efficiency and orderliness.

Figure 3 : Tools and equipments on tabel before and after set in order.

S3 Shine(Seiso):

Machines are kept clean, free from oil and chips, ensuring a hygienic environment. The floors are dry, with a designated individual supervising the cleaning operations. Labels and signs remain in a clean and intact condition as shown in Figure 4. A-B.

(A) (B)

Figure 4 .A-B **:**Clean Shop floor and machines (shine).

S4 Standardize (Seiketsu):

It is essential to uphold the foundational three S's. This involves ensuring that standard operating procedures are not only clear but also comprehensively documented. Additionally, promoting a culture of continuous improvement is crucial, achieved through the execution of innovative ideas within the work process [21].

S5 Sustain(Shitsuke):

Regularly review standard procedures, ensuring correct placement of tools and parts. Keep activity boards up to date, emphasizing the significance of education and communication. It is essential to establish a system that acknowledges and recognizes the efforts of workers. Implementing an award and reward system becomes essential to motivate and provide incentives to employees for their valuable contributions to maintaining a clean, organized, and efficient workplace.

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Kaizen implementation:

Kaizen 1

Objective: To optimize the scrap collection process in the stamping unit through the execution of Kaizen principles.

Problem: Lack of a designated trolley for efficient scrap collection in the stamping unit.Due to which extra time required to handle scrap.

Problem analysis: Scrap on workshop floors creates safety hazards, reduces productivity, increases equipment wear and tear, reduces quality control, and lowers worker morale

Root cause: The root cause of the problem lies in the lack of a structured and dedicated system for scrap collection.

Action: Introduce a designated trolley for scrap collection within the stamping unit as shown in Figure 5.A-B.

Benefits: Having trolleys available for scrap handling Increases overall operation Efficiency,cost redcution,enhanced safety and Improved Workplace Organization.

Kaizen 2

Objective: To decrease the time and cost associated with die setting.

Problem: Non availability of screw jack, leading to prolonged tool clamping times (2 minutes per tool for 4 clamps).

Problem analysis: Extended die setting times were adversely affecting production output.

Root cause: Lack of accessible screw jack for efficient tool clamping.

Action: Installation of screw jacks for each machine as shown in Figure 5.C-D.

Benefits: 1)Reduction in tool clamping time. 2)Time savings of 1 minute per tool, with an average of 325 tool settings per month, resulting in a total monthly time savings of 5.4 hours. 3)Increased production quantity.

(A)

(B)

(C)

(D)

Figure 5. A-B : Kaizen Transformation in Scrap Collection Efficiency C-D : Kaizen Transformation in Enhancing Die Setting Efficiency

IV. Discussion

The findings of research provide important insights into the ergonomic challenges and the effectiveness of lean manufacturing tools in addressing musculoskeletal disorders (MSDs) in a manufacturing environment. The study revealed a high rate of MSDs among workers, with over 74% reporting upper back discomfort and 60% experiencing lower back pain. This highlights the urgent need to address ergonomic risks to prevent health problems and productivity losses.Generally, the research captured various worker postures encompassing standing, squatting, and lifting among others, each of these exposing specific ergonomic hazards. This diversity would call for an overall strategy for ergonomics applied at this level to be specific to each posture type with interventions aimed at reducing strain at all recognized work positions.

Furthermore, the application of ergonomic assessments such as the Nordic questionnaire and Rapid Upper Limb Assessment (RULA) was found to be effective in identifying and quantifying ergonomic risks, thereby guiding targeted interventions.

The findings align with existing literature that emphasizes the negative impact of neglecting ergonomics at work. Previous studies have shown that ergonomic interventions can reduce injury rates and enhance worker performance [7]. For instance, research in the textile industry has shown that ergonomic redesign can alleviate musculoskeletal discomfort and improve productivity [9]. This study supports these conclusions, showing that combining ergonomic assessments with lean manufacturing practices leads to better worker safety and operational efficiency.

From a practical perspective, the integration of lean tools such as 5S and Kaizen proved to be highly effective. These tools not only reduced waste but also enhanced workplace organization and safety. The implementation of 5S resulted in a cleaner workspace, which is crucial for maintaining efficiency and reducing injury risks. Kaizen initiatives like adding trolleys for scrap collection and installing screw jacks for tool clamping showed clear improvements in operational efficiency and worker safety.

While this case study provides useful information, it is vital to recognize its limitations. The study was done within a single division of a manufacturing organization, which may restrict the generalizability of the results. Future research should explore how ergonomics and lean manufacturing can work together in different types of industries. This will help confirm and expand on what we already know. As part of my ongoing research, the study looking at this combination in three distinct industries. This work will add to our understanding and provide more evidence about the benefits of integrating these approaches.Furthermore, longitudinal studies may provide more insight into the long-term effects of ergonomic changes on worker health and organization productivity.

V. Conculsion

The work presented in the paper successfully demonstrated the synergistic benefits of integrating ergonomics and Lean manufacturing in a manufacturing environmnet. By implementing an integrated approach that combined ergonomic assessments with Lean tools like 5S and Kaizen, the study achieved significant improvements in worker safety, health and efficiency. The study revealed a concerningly high prevalence of MSDs among workers, particularly in the upper and lower back. This highlights the need for immediate intervention to address ergonomic risks and prevent further musculoskeletal health problems. The implementation of 5S methodology showcased positive outcomes, with improvements in workplace organization, cleanliness, and overall efficiency. Two Kaizen initiatives addressed specific challenges in scrap collection and die setting, demonstrating a proactive approach to continuous improvement. The findings are usefull for similar industrial settings to promote worker well-being, enhance productivity, and create a safer and more efficient work environment.

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