Positive Impacts of Integrating Lean Methodologies and Ergonomics—A Literature Review

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Abstract In the last decades, more and more companies have adopted continuous improvement strategies to increase competitiveness. To that end, Lean Manufacturing is one of the most used approaches. However, the workload imposed by Lean manufacturing can be higher than the workers' capacity. Understanding how the workload demanded by the Lean models affects workers' health and well-being became highly relevant to the companies. This work carried out a literature review on the topic. It aims to clarify the actual impacts for companies of integrating Lean Methodologies with Ergonomics. Moreover, it is expected to enhance the most common ergonomic methods used. The research was performed on two highly regarded scientific databases, the Scopus and Web of Science, and included articles published between 2013 and 2022. A total of 16 articles were selected based on the inclusion criteria. Results show that a few studies focus on the relationship between Continuous Improvement and Ergonomics. Nevertheless, the articles analysed evidenced the positive effects of integrating the two areas, both for companies and workers. In addition, the integrated approach enables the identification of the risk factors imposed by the Lean methodologies and the definition of adequate strategies to mitigate the risk.

Keywords Lean · Ergonomics · Continuous improvement · Risk assessment

1 Introduction

Several companies worldwide have adopted Lean methodologies to improve operational performance (Sakthi Nagaraj et al. 2019). Lean Thinking focuses on eliminating everything that does not directly contribute to the added value of a product

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from the perspective of customer needs and requirements (Arezes et al. 2015). As a result, products have better quality at the lowest cost and with the shortest lead time by reducing the production flow, eliminating waste, and involving labor (Costa et al. 2019). This approach comprises four subsystems: Just-In-Time (JIT) manufacturing, Quality Management (QM), Total Preventive Maintenance (TPM), and Human Resources (HR) management practices (Longoni et al. 2013).

When well implemented, Lean provides benefits such as the possibility of task variety, job security, financial incentives, and worker autonomy (Tortorella et al. 2017). However, it is estimated that only about 10% of the companies that adopted Lean methodologies managed to implement them sustainably (Sakthi Nagaraj and Jeyapaul 2021). One of the reasons why results are not as good as expected is that many companies focus only on Lean tools and techniques, neglecting Human Factors and Ergonomics (Alsaffar and Ketan 2018a; Sakthi Nagaraj et al. 2019). Lean production is more demanding on a muscular, cognitive, and emotional level since it increases the pace and workload, leading to fatigue and stress (Nunes 2015; Stimec and Grima 2019; Vukadinovic et al. 2019; Colim et al. 2021).

The problem can be more significant if workers do not report their illnesses and refrain from reporting injuries or requesting sick leave, which is common when they suffer from pressure imposed by their colleagues (Koukoulaki 2014). In addition to this, there is a tendency for companies to neglect the comparison between the required workload and the actual workload, both psychologically and physically (da Silva et al. 2016).

The main objective of Ergonomics is to develop and apply techniques to adapt man to his work efficiently and safely, optimize well-being and consequently increase productivity (Santos et al. 2015).

To ensure companies' continuous improvement without compromising workers' health and well-being, integrating Lean Management techniques and ergonomic methods is extremely important. This integration may boost productivity, improve working conditions, and reduce worker absenteeism (Colim et al. 2021).

Several authors suggest different methodologies that intend to integrate Hard Lean, namely the production process, and Soft Lean, a practice related to humans and their interaction with the system (Sakthi Nagaraj et al. 2019). Although these methodologies come from different authors, they have the same goal to improve the physical and psychological aspects of workers' health while ensuring the company's economic success. Although there is a growing concern in several entities, this is still not considered a priority theme (Longoni et al. 2013).

A short literature review on the subject was developed to understand and identify what has been done in recent years regarding applying Lean methodologies and ergonomic assessment methods. To this end, two research questions (RQ) were formulated:

RQ 1: Which ergonomic methods have been applied to assess the risk imposed by Lean methodologies?
RQ 2: What are the positive impacts of integrating Lean Methodologies and Ergonomics?

The article is organized as follows: Section 2 describes the Research Methodologies where the research is described; Section 3 includes a detailed analysis of the selected articles; and Sect. 4 provides a Conclusion of the main findings.

2 Research Methodology

This research consists of a systematic literature review to evidence the work that has been developed in the recent years among the application of Lean methodologies integrated with Ergonomics. The study aimed to understand it by answering the two research questions described in the previous section.

While conducting the research, the following inclusion criteria were considered:

- Articles published between 2013 and 2022;
- Articles that are written in English;
- Articles that integrated Lean methodologies with Ergonomics.

The search was conducted using Scopus and Web of Science and combined four keywords: Ergonomics, Continuous Improvement, Lean, Kaizen and DMAIC.

Initially, 271 articles were found in the two research databases. After analyzing their titles, keywords, and abstracts, only 30 articles were selected to be deeply analysed. Finally, after a thorough screening, it was verified that only 16 articles followed the third inclusion criteria. Therefore, 16 articles were used to pursue this research work.

3 Results

The 16 articles carefully analyzed. Table 1 summarizes the articles and points out the associated benefits.

3.1 Model Proposal Through a Case Study

One of the studies consists of developing the Ergo-VSM tool in the textile industry. Authors initially defined a set of metrics related to the ergonomic aspects studied (e.g., psychological, and physical factors) and the Lean ones (e.g., cycle time). Measurements were taken to quantify the different Lean metrics. Subsequently, the operation under study was divided into different tasks to which ergonomic scores were assigned (obtained through observation and questionnaires). These were considered low, medium, or high risk depending on the score obtained. Thus, ergonomic measures were implemented according to the risk level. Finally, the parameters were

Table 1 Summary of the articles analysed

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Sakthi Nagaraj et al. (2019)	Model proposal through a case study	Physical Psychological Organizational Risks	Development of the Ergo-VSM tool, in the textile industry, to evaluate the risk level of each operation task. After the evaluation, a set of ergonomic measures were developed	Improved workers' quality of life and organizational performance Healthier organizations (for workers and management)
da Silva et al. (2016)	Model proposal through a case study	Physical Psychological	Development of a model, in the automotive industry, to identify the differences between estimated and actual work required at the ergonomic level	Understanding ergonomic factors in the implementation of Lean methodologies and where to act in the medium and long term
Botti et al. (2017)	Model proposal through a case study	Combining Ergonomics with Occupational Safety	The ILP model seeks to find the optimal sequence of an assembly line in a toolbox production. It includes an ergonomic evaluation using the OCRA index and two functions that drive its optimization: one addresses the Lean principles of JIT production and WIP reduction; another aims to reduce the overall cost of the hybrid assembly system	Respect for ergonomic principles of occupational health and safety Assembly line optimization WIP and cost minimization

(continued)

Table 1 (continued)

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Alsaffar and Ketan (2018b)	Model proposal through a case study	Musculoskeletal injuries	Development of a methodology, in the automotive industry, that combines Ergonomics principles, through job rotation, with Lean approaches, Muda waste and SS with DMAIC phases focused mainly on WIP efficiency and Ergonomics	Reduce waste, NVA, and musculoskeletal injuries Increased efficiency Improved ergonomic conditions
Alsaffar and Ketan (2018a)	Model proposal through a case study	Risks inherent to the workstation	Model applied in the automotive industry based on the integration of LSS and Ergonomics by designing a diagnostic ES that combines time-wasting-centric tools Mura and RULA. This identifies the risk level regarding posture as part of the Lean practice used at workstations	Simple methodology although highly efficient in the implementation of productivity measures and assessments and ergonomic actions Increased assembly line efficiency by reducing Mura waste

(continued)

Table 1 (continued)

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Vukadinovic et al. (2019)	Methodology development	Human Resources Management	Creation of the "Early Management and Human Resources development" technique that recommends 7 steps to be developed by companies. They claim that if the steps are carried out successfully then the workers will exhibit safer and more ergonomic behaviors without the need for training	Increased cooperation between companies and educational institutions New workers start working at 100%, without the need for training or eliminating the problem of inadequate preparation
Tortorella et al. (2017)	Model proposal through a case study	Physical Psychological	Use of questionnaires and a mathematical model to verify risks of Lean and Ergonomic methodologies applied in the automotive industry. Thus, it was possible to prioritize the improvement opportunities to be implemented according to the level of risk	Improving long-term ergonomic issues Identifying gaps in the Lean process by anticipating problems
Colim et al. (2021)	Methodology development	Musculoskeletal injuries	Evaluation of the effect of implementing robotic technology, in a board production, through KPI's related to Lean metrics and ergonomic characteristics	Reduction of production times, cycle times, and raw material consumption Improved ergonomic conditions and worker well-being

(continued)

Table 1 (continued)

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Longoni et al. (2013)	Methodology development	Combining Ergonomics with Occupational Safety	Development of a methodology, in the production of metal, plastics and furniture, based on a Service Profit Chain (SPC) model to verify the impact of implementing different Lean methodologies on ergonomics and occupational safety	Lean impact reduction in Ergonomics and Safety when the methodologies are applied in an integrated and correct way, with emphasis on human resources
Sakthi Nagaraj and Jeyapaul (2021)	Model proposal through a case study	Physical Psychological Organizational Risks	Through an SEM-based analysis it was possible to calculate the correlation between physical, psychological, management, workplace design, and cognitive factors with Lean performance and a positive influence was found	Relevance of considering human and organizational factors when implementing practices that achieve sustainable results

(continued)

Table 1 (continued)

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Nunes (2015)	Methodology development	Physical Psychological	Development of a DSS to assist managers with the activities required by each phase of the DMAIC cycle. This helps the choosing and application of the tools and methods used by the Ergonomics and LSS paradigms, in the integrated implementation of continuous improvement in enterprises	Integration of Ergonomics during LSS implementation Substantial productivity gains and improved working conditions
Brito et al. (2020)	Methodology Improvement	Combining Ergonomics with Occupational Safety	Improvement of ErgoSafeCI methodology adapting it to the plastic packaging sector, in which ergonomics was divided into Physical and Organizational and Cognitive. The software itself has been improved to make it more automated	Improved productivity and worker conditions Improved ErgoSafeCI tool making it easier to apply
Stimec and Grima (2019)	Interviews/Questionnaires	Occupational stress	Questionnaires and interviews were conducted to identify the relationship between Lean methodologies applied to production and the occupational stress caused by them	Positive effects on workers' stress and absenteeism Rapid identification or anticipation of work impeding factors

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Table 1 (continued)

References	Study type	Ergonomic aspects	Aim of the study	Benefits of including the approach
Santos et al. (2015)	Interviews/Questionnaires	Physical Psychological	Questionnaires and interviews were conducted in an automotive industry, to identify workers' opinion regarding the workstation, considering ergonomic factors and the application of methodologies to the production system. It is possible to verify where the company needs to act and how the working conditions must be improved	Top management awareness of workers' health Reduction of accident risk in the workplace Improved product quality
Afonso et al. (2022)	Model proposal through a case study	Musculoskeletal injuries	The proposed ESMED model successfully integrated SMED and ergonomics in a detailed and well-defined approach aiming the reduction of the risk associated with injuries and streamline setup processes	Reduction of the risk level of Work-Related Musculoskeletal Disorders Increased production efficiency
Mrugalska (2020)	Methodology development	Combination of ergonomic with lean competences	An integrated model of lean and ergonomic competencies is presented, and these initiatives are shown at different stages of their development	Organizational vision and focus on value systems, Creation of beneficial relationships, dynamic coaching and problem solving, Attempt for improvement and development

measured once again. Significant improvement was verified (Sakthi Nagaraj et al. 2019).

Another study focused on developing a tool that identifies the differences between estimated and actual work. First, different physical and psychological criteria were defined to be evaluated. Then, questionnaires and observations were performed to analyze the Lean production cells and their operations. Finally, the actual physical and psychological demands were classified, and the difference between these and those estimated by management was calculated (da Silva et al. 2016).

Integer Linear Programming (ILP) is another model that aims to find the optimal sequence for an assembly line. The model assigns workers or machines to each workstation given the characteristics of the assembly process and the working parameters of the machines. Each assembly sequence includes ergonomic risk assessment using the Occupational Repetitive Actions Index (OCRA) to meet occupational health and safety requirements. Two functions drive the optimization of this model. First, one addresses the Lean principles of JIT production and Work in Progress (WIP) reduction. Another aims to reduce the overall cost of the hybrid assembly system (Botti et al. 2017).

Finally, two other studies developed the "LSS + Ergo" methodology, starting by identifying the 7 Muda wastes in each workstation.

Subsequently, for the first study, two models were created:

- Efficient Process Flow and Time—to prevent Muda by implementing effective and appropriate Lean tools.
- Working Condition versus Ergonomics—assessment of losses from an ergonomic perspective.

Both models have been integrated into an Expert System (ES) that aims to facilitate the execution of the DMAIC cycle. Finally, it was possible to derive practices that should be implemented, such as job rotation, to reduce waste, NVA activities, and risks and injuries associated with the job (Alsaffar and Ketan 2018b).

The second study proposes the same ES; however, this one combine tools focused on time-wasting, such as Mura and Rapid Upper Limb Assessment (RULA). It identifies the risk level associated with postural movements as part of the Lean practice used at workstations. First, the ergonomic problems and risk factors associated with the workstations were identified. Then, RULA was used to calculate the risk level of musculoskeletal disorders. Finally, the results that correlate Mura waste with ergonomic working conditions were obtained along with the measures that should be applied (Alsaffar and Ketan 2018a).

The last case study reviewed proposes an Ergonomic solution based on Lean Manufacturing in the metalworking industry based on continuous improvement. Through the application of RULA, the need to make immediate changes in the process activities was found. Implementing a Lean practice made it possible to, after the integrated application of Lean and Ergonomic tools, verify an improvement in several metrics associated with them. This study has shown that the lack of an ergonomic analysis can be considered a waste within the Lean philosophy. When applied in

organizations, it can increase efficiency and promote the continuous elimination of waste, ensuring financial and workers' health (Miguez et al. 2018).

3.2 Methodology Development

The first article in this section (Vukadinovic et al. 2019) was based on the creation of the "Early Management and Human Resources Development" technique, summarized as follows:

- Focus on training the company's human resources in Lean knowledge. Thus, in the recruitment process, they will be able to identify the characteristics of the candidates that are best suited for the job.
- They recommend a merger between companies and universities to train future candidates to use ergonomic guidelines when exposed to Lean methodologies.

Another study (Tortorella et al. 2017) shows that workers were exposed to Lean work practices; however, sustainable work was never adopted, especially regarding ergonomics. Thus, a method consisting of 3 steps was applied:

- Determination of Lean and Ergonomic practices adopted in the company through two questionnaires given to senior individuals.
- Through creating a mathematical model, it was possible to calculate the risk level of Lean methodologies.
- Consolidation and prioritization of improvement opportunities according to risk level.

Another methodology studied is related to the high manual work in the assembly of frames that causes musculoskeletal injuries. Implementing more ergonomic ways of working was necessary through more robotized work. Before and after implementing the robotic technology, the workstation was evaluated to understand whether the tasks brought value by measuring different key performance indicators (KPIs). Subsequently, an evaluation of the ergonomic characteristics was performed using three evaluation methods: RULA, Revised Strain Index (RSI), and Key Indicator Method for assessing physical workload during Manual Handling Operations (KIM-MHO). Finally, a questionnaire was conducted to assess workers' perceptions of the inclusion of a hybrid industry (human and robot labor) and the associated ergonomic improvements (Colim et al. 2021).

The Service Profit Chain (SPC) model (Longoni et al. 2013) is based on different industries, such as metal, plastics, and furniture manufacturing. The different phases that involved the creation of the methodology consisted of:

- Conducting interviews and sending anonymous forms to understand the previously selected companies better. In these forms, it was asked which Lean methodologies are currently applied.

- From the data collected, the companies were divided into four groups according to the 4 Lean methodologies considered most important to the researchers (JIT, QM, TPM, and HR).

The role of HR for Ergonomics and Occupational Safety was found to be vital when compared, for example, with companies that only implemented JIT (Longoni et al. 2013).

Another study performed a Structural Equation Modeling (SEM) analysis (Sakthi Nagaraj and Jeyapaul 2021). It was based on the following phases:

- Separating the subjects under study into six branches: physical, psychological, management, workplace design, cognitive factors, and Lean performance.
- Selection of 29 measurement items used to construct online questionnaires and telephone interviews to assess the six branches.
- Development of a measurement model after data collection allowed studying the correlation between physical, psychological, management, workplace design, and Lean performance factors, with a positive influence.

The last methodology studied consists of developing a Decision Support System (DSS) that allows managers to be assisted in the activities required by each phase of the DMAIC cycle. The objective is to help choose and apply the tools and methods used by the Ergonomics and Lean Six Sigma (LSS) paradigms in the integrated implementation of continuous improvement (Nunes 2015).

3.3 Methodology Improvement

The study is based on the improvement of the ErgoSafeCI tool. The objective was to improve ergonomic and safety conditions for workers while maintaining productivity and a focus on performance indicators. Firstly, all the issues belonging to the tool were analyzed to understand whether they should be adapted to the productive reality of the plastic packaging sector. Secondly, a literature review on Lean, Safety, and Ergonomics was done to improve the tool's questions. From this analysis emerged the separation of Ergonomics into three parts: Physical, Organizational, and Cognitive. In addition, some questions had to be added to the tool to improve the evaluation of the jobs. The third phase improved the software, mainly by automating as much as possible to make the tool easier to use. Finally, based on the results obtained, improvements were introduced to increase the productivity and well-being of the workers (Brito et al. 2020).

3.4 Interviews/Questionnaires

In the first phase, questionnaires and interviews were conducted to understand what happens on the "shop floor" (Stimec and Grima 2019). The goal was to identify the links between Lean (namely Continuous Improvement) and occupational stress based on three questions:

- Characterization of continuous improvement. This was defined based on training and education, management commitment and involvement, and worker participation and empowerment. It was found that the workers had already received the training. The remaining factors were evaluated based on the data collected. A panel of experts assessed the level of continuous improvement and Lean performance.
- Industrial performance: the expert group classified industrial performance into 3 levels.
- Occupational stress performance: the experts relied only on psychometric questionnaires.

Finally, in the last method analyzed, questionnaires and interviews were conducted to identify the workers' opinions regarding the workstation, considering ergonomic factors and the organization and application of methodologies to the production system. After collecting the data, it is possible to ascertain the situation regarding Lean concepts that have been applied to production correlated to Ergonomics and Working Conditions. In this way, it is possible to see where the company needs to act and how the working conditions need to be improved (Santos et al. 2015).

4 Discussion and Conclusions

Worldwide, several companies have started to adopt Lean methodologies to achieve excellent performance through a culture of continuous improvement in a very competitive environment. It happens because Lean methodologies, when well implemented, provide better operational and financial performance for a company.

However, although there is a concern with implementing Lean methodologies, the same concern is not witnessed for integrating ergonomic strategies from the initial stage. It can be seen by comparing many studies on Lean and the small number of studies that consider the integration of both topics.

This review article considers different methodologies and studies that demonstrate the importance of integrating Ergonomics with Lean and Six Sigma methodologies. Many include questionnaires, interviews, DSS, ES, and even mathematical models. The literature research developed focused on two research questions.

Regarding RQ1, it was verified that most authors had used questionnaires and interviews conducted primarily with engineering or Lean professionals. These are the primary purpose of obtaining the data needed to create the tools. Overall, we can say that the integrated ergonomic assessment methods depend on the type of Lean

methodologies implemented by the companies since they may represent different risk factors and different risk levels. For example, if the focus is to quantify wasted time, combining the MURA reducing tools from Lean with the standard ergonomic assessment methods (e.g., RULA) is expected. Another example is robotization through Lean metrics but designed with ergonomic characteristics. This combination improved productivity and provided benefits for the worker as the monitoring and control of interfaces replaced manual and repetitive work.

In addition, the research demonstrated that many authors proposed and implemented integrated models that are very specific to a company or to a type of industry. A relevant topic for future studies would be identifying complementary criteria to ensure that the models could be used in different companies or contexts.

Regarding RQ2, the research showed that combining Lean methodologies and ergonomic principles can positively impact an organization. Through the 16 articles used in this research, it was possible to identify numerous benefits associated with this integration. Among the benefits, the following should be highlighted:

- Development of practices that benefit both Lean implementation and worker from an ergonomic point of view. An example is the job rotation that eliminates waste and reduces the risk of injury.
- Prioritization of opportunities for continuous improvement based on the ergonomic risk level obtained by specific methods; in this way, the organization realizes where it should act in the short and medium term.
- Improvement of workers' quality of life by reducing the stress and the risk of musculoskeletal disorders/work accidents.
- Improvement of the organization's performance by reducing production times, cycle times, and resources and, consequently, reducing costs and increasing productivity and quality.
- Increased awareness of top managers regarding workers' health.

As a result of this research, it can be concluded that the integration of Lean and Ergonomics is an asset for both companies and workers.

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