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SYSTEMATIC LITERATURE REVIEW: LEAN ERGONOMICS ANALYSIS IN SMALL & MEDIUM ENTERPRISES (SMEs) MANUFACTURING SECTOR

Norhana Mohd Aripin, Fatimah Mahmud, Lee Khai Loon and Suhaidah Hussain

Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia

Corresponding author: norhana87@gmail.com

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ABSTRACT

Ergonomics has emerged as a significant workplace issue, negatively impacting finances due to worker absence and reduced productivity. Small and Medium Enterprises (SMEs) are particularly prone to occupational accidents, contributing to over 80% of such incidents. This review delves into the perspective of lean ergonomics within SMEs. The study followed a structured review protocol, formulating research questions and systematically searching the Scopus and WoS databases. The findings reveal several key points: (1) SMEs commonly implement ergonomics principles addressing awkward postures, repetitive movements, manual material handling, hand-wrist postures, excessive reach, grip strength, and prolonged standing; (2) Lean principles such as SMED, 5S, standardized work, TPM, VSM, and kanban positively impact ergonomics; (3) Various ergonomics assessment methods, including REBA, RULA, HFE, JSI, KIM, OCRA, and Shoaf's model, are recommended for future research and practical application; (4) Ergonomics can underpin lean transformation efforts, with Lean Manufacturing (LM) contributing to reduced ergonomics risks. However, the review identified a limitation in the scope of databases used (WoS and Scopus), suggesting that expanding the range of databases and research keywords could improve future article searches. The study's primary focus serves as a reference point for future researchers and manufacturers interested in lean ergonomics, emphasizing the need for comprehensive approaches to enhance worker safety and productivity through ergonomic and lean practices.

Keywords: Lean manufacturing, ergonomics, lean ergonomics, SMEs.

INTRODUCTION

The ongoing and fast expansion of the manufacturing industry is putting a lot of strain on the environment, natural resources, and social beings (Molamohamadi & Ismail, 2014; Sadiq et al., 2023). The United Nations general assembly put out the Sustainable Development Goals (SDGs) as a framework for sustainable development in 2030 with 169 specific targets, including several targets for workplace safety and health, namely; (1) SDG 3: ensure healthy lives and promote well-being for all at all ages, (2) SDG 8: promote sustained, inclusive and sustainable economic growth, and full and productive employment and decent work for all, and (3) SDG16: promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels (Ávila-Gutiérrez et al., 2022; Jayasooria, 2016).

Ergonomics issues have become one of the most prevalent workplace issues in recent years, severely limiting people's everyday activities (Zaheer et al., 2023). Worker health problems, such as work-related musculoskeletal disorders (WMSDs), have been attributed to non-ergonomic workstations that push employees into awkward workplace postures (Hosseini et al., 2022). Ergonomics risk in the workplace can result in significant injuries and influence workers' health and quality of life (Vijayakumar & Robert, 2022). Moreover, ergonomics issues have a negative financial impact directly and indirectly through absence and reduced production output. This financial loss will also impact people, communities, and industries (dos Santos et al., 2015; Vijayakumar & Robert, 2022). Many manufacturing companies are becoming more interested in the expanding discipline of ergonomics and human factors as a method of designing their products and processes in light of the current pressuring demand and conditions (Reiman et al., 2021).

Lean manufacturing (LM) has benefited a wide range of industries, and this methodology aids competitiveness in several segments by eliminating manufacturing waste (dos Santos et al., 2015; Swarnakar et al., 2022). The goal of using LM is to streamline the manufacturing process from acquiring raw materials to finish-good products. The goal of LM, which originated in Japan in the 1950s, is to eliminate wastes such as overproduction, waiting, motion, overprocessing, inventory, transportation, and defect systematically and continuously (Bouranta et al., 2022). On a managerial level, LM is translated into various LM practices and tools such as just-in-time, total productive maintenance, and total quality production (Galeazzo & Furlan, 2018; Rao & Niraj, 2016).

Manufacturers' perceptions of LM have shifted due to further expansion associated with ergonomics issues (Brunner et al., 2022). The introduction of the ergonomics factor is lean sparked when there were startlingly high incidences of ergonomics problems at the workplace, and the ergonomic issues had been optimized with LM measures. Earlier, the ergonomics impact was unknown when it was decided to introduce an explicit LM method based on the findings of Womack et al. (2007). To comprehensively increase productivity while safeguarding worker performance and health, lean ergonomics (LE) comprises the integrated LM and ergonomics approaches were introduced. Although the philosophy of LM and ergonomics are too far apart, integrating them has proven to provide a positive relationship (Brunner et al., 2022). According to Nunes (2015), ergonomics improvements were only made due to accidents, frequent sick days, and health issues since top management failed to see an obvious explanation before these occurrences.

According to Samin and Abdol Rahman (2021), small and medium-sized enterprises (SMEs) are the biggest contributor to the total number of business establishments, accounting for 98.5%. Unexpectedly, Abdol Rahman and Samin (2022) discovered that SMEs were more responsible for occupational

accidents than larger businesses. Compared to large companies, SMEs lack the financial capability to develop and implement safety programs to comply with safety compliance. Moreover, SMEs accounted for between 80 and 90 percent of all occupational accidents (Rahman et. al 2021). Hence, due to this high contributing factor of occupational accidents in SMEs, this review is interested in looking deeper into the perspective of LE among SMEs.

Despite the large amount of literature on LE, nothing has been done to systematically review, identify trends, and develop thematic on LE among SMEs. The closest work conducted by Brito et al. (2019) finds the integration of both LM and ergonomics principles. The review concluded that workstation design could improve worker welfare and increase manufacturing productivity. However, the studies were general and not specified to SMEs. Hence, this review is interested in looking deeper into LE among SMEs because they contribute to more occupational accidents than larger companies. Because of conscious employees and strict labor laws, SMEs are also under increased pressure to enhance their workplace health and safety. The competitive workplace is also increasing the pressure on SMEs to integrate their corporate strategy to synergistically enhance operational and employee performance (Sakthi Nagaraj et al., 2019).

Hence, under this current pressuring demand on LE among SMEs, this study proposes conducting a systematic literature review (SLR) focusing specifically on LE among SMEs in the manufacturing industry to fill this literature gap. SLR can support the authors' empirical evidence, point out research gaps, and guide future studies. Hence, the main research question guided the researchers as they progressed through the review; (1) What are the ergonomics principles, lean principles, and ergonomics assessment tools used by the SMEs manufacturers? and (2) How lean and ergonomics integrates towards operational performance?

METHODOLOGY

This section outlines how researchers obtain publications related to SMEs LE. The process includes strict protocols and methods that examine the relevant articles. Frequently used methods for conducting literature reviews are Preferred Reporting Items for Systematic Reviews (PRISMA) and Meta-Analyses. It serves as the foundation for the approach used to identify the articles. The review report, which evaluates randomized trials and may be used as a starting point for doing systematic reviews, is highlighted by PRISMA. It also contains exclusion and inclusion criteria for relevant publications in this review (Moher et al., 2009). According to Moher et al. (2009)., PRISMA can be used for a systematic review emphasizing randomized trials as the foundation for other types of research, such as intervention, which can present several challenges, particularly when assessing qualitative and mixed-method study designs.

PRISMA ensures that no significant study is missed by searching multiple scientific information databases and all possible research possibilities (Rosa & Broday, 2018). Given the research selection criteria, the screening strategy may be able to minimize the amount of research identified (Moher et al., 2009). PRISMA is frequently used in medical studies but is ideal for operations management since it emphasizes research issues connected to the need for a systematic review. This strategy could also offer inclusion and exclusion standards for a specific study. Academics from a range of disciplines, not only medicine, have been forced to examine more methodologically-based publications on SLR due to the lack of methodological direction in research and the scarcity of current methodological references.

Two key databases, Scopus and Web of Science, were used to conduct the review techniques for this study (Innocent et al.). The most prominent scientific publications in these two databases may be regarded as dependable sources with substantial collections of academic material (Paul & Criado, 2020). Scopus is one of the biggest abstract and citation databases for peer-reviewed publications. Thus, it has been chosen to obtain the articles. It covers a range of disciplines, including social science, agriculture, and biology, and contains more than 22,800 journals from 5000 publishers worldwide (Shaffril et al., 2018). WoS is a large database with information from over 33,000 publications, comprehensive back files dating back over 100 years, and Clarivate Analytics citation data. WoS rates journals based on three criteria: articles, citations per publication, and citations. Nonetheless, it should be remembered that no database, including Scopus and Web of Science, is perfect or comprehensive.

The inclusion criteria for the selected articles were journal articles and conference proceedings. However, review articles, book chapters, and books were the criteria for exclusion. While many reviewers did not include conference proceedings, this study followed the suggestion of Podsakoff et al. (2005) to include these criteria since conference proceedings are subject to academic evaluation and hence more generally recognized as a higher quality source. The inclusion of conference proceedings allows academics to broaden their knowledge of LE among SMEs to conduct a more thorough study. To avoid misunderstanding, only those written in English were considered. Furthermore, only empirical studies were chosen because this review aims to better understand the empirical findings of LE concepts in SMEs. In summary, Table 1 displays the inclusion and exclusion criteria of the article search.

Table 1

Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Journal articles, Conference proceedings	Review articles, book chapters and books
English language articles	Non-English language articles
Empirical study	Conceptual study and review article

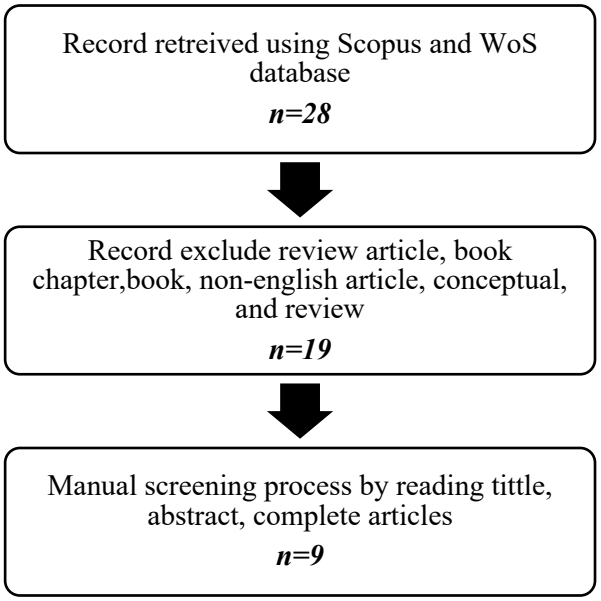
Scopus and WoS search strings were used to find all related terms to this review. Based on the research questions, three important keywords were identified: lean, ergonomics, and SMEs. Previous research was used to explore synonyms, similar phrases, and variants to expand the study keywords. These keywords were then searched in the advanced database tool, and 28 articles were discovered from the database based on the search attempts. Finally, 19 articles were continued after the exclusion criteria were eliminated. According to Kraus et al. (2020), the author's capacity to complete the review article usually impacts the quality of the literature review. Although the overall number of papers retrieved was low, with a total of 19, this strongly indicates that further scientific study on this specific issue, in this case, SMEs, is required (Banha et al., 2022). In addition, according to Frank and Hatak (2014), a lower number of articles is plausible in the areas that are still expanding, as fewer articles can also be justified for an SLR that covers a very specific topic LE among SMEs.

From the 19 articles, the authors manually evaluated the remaining works by reading the titles, abstracts, or whole articles to ensure relevant theories underpinned the articles. Ten articles were eliminated during this stage due to the abstract and whole article reading screening procedures. The article was

removed because of duplication between Scopus and WoS (n=3), conceptual study (n=2), and no detailed info on ergonomics principles (n=5). Hence, nine articles were considered valid for further analysis. Figure 1 depicts a comprehensive flow diagram of the search process. The next section will explain the result and analysis based on the selected articles.

Figure 1

Search Process Flow Diagram



RESULTS

The descriptive analysis was conducted from 9 articles based on specified research string of “Lean”, “Ergonomic”, and “SME”, inclusion and exclusion criteria, and manual screening process. Regarding the year of publication, 2011, 2017, and 2019 published one article each. However, there is an obvious spike of articles published in 2020 with two articles and in 2022 with four articles, displaying that this issue is an emerging topic for manufacturers. Figure 2 depicts the information on the publication year of related articles.

In terms of the publisher, in summary, two articles were published in Sustainability and Procedia Manufacturing. Meanwhile all other publishers published one article (i.e., Advances in Intelligent Systems and Computing, Advances in Industrial and Manufacturing Engineering, Production Planning & Control, World Academy of Science, Engineering and Technology, and Materials Science and Engineering). Figure 3 summarizes the journal and the number of articles published.

Figure 2

Publication Year

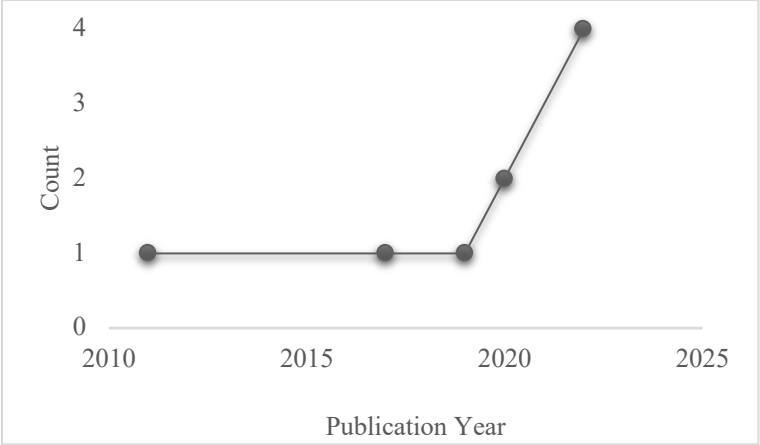
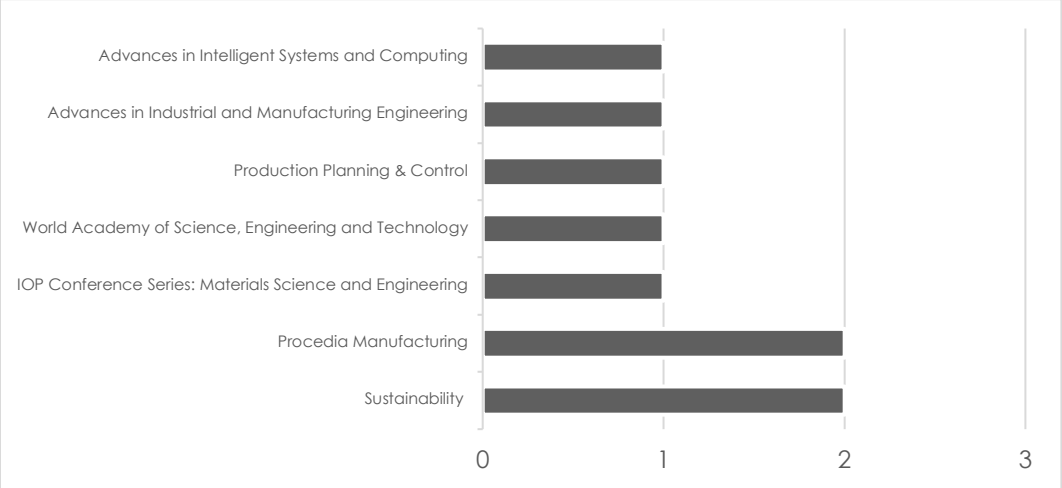


Figure 3

Published Journal



Ergonomics Principles in SMEs

The result was further analyzed from 9 articles based on specified research string, inclusion and exclusion criteria, and manual screening process. The first sub-section answers the first research question on "What are the ergonomics principles, lean principles, and ergonomics assessment method used by the SMEs manufacturers?" Hence, this section reviews the ergonomics principles used in relation to LE among SMEs. In summary, Table 2 displays the ergonomics principles used by previous researchers.

Table 2

Ergonomics Principles

No	Ergonomics Principles	Count(s)	Literature (s)
1	Awkward posture	7	(Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Kose et al., 2022; Rathore et al., 2022; Sari et al., 2019)
2	Repetitive movement	6	(Afonso et al., 2022; Brito et al., 2020; dos Santos et al., 2015; Fonda & Meneghetti, 2022; Kose et al., 2022; Rathore et al., 2022)
3	Manual materials handling	5	(Afonso et al., 2022; Brito & Gonçalves, 2020; Kose et al., 2022; Sari et al., 2019; Ulutas, 2011)
4	Hand–wrist posture	4	(Afonso et al., 2022; Fonda & Meneghetti, 2022; Kose et al., 2022; Rathore et al., 2022)
5	Extreme reach	3	(Brito & Gonçalves, 2020; Brito et al., 2017; Sari et al., 2019)
6	Grip strength	1	(Afonso et al., 2022)
7	Prolonged standing	1	(Rathore et al., 2022)

Previous researchers highly mentioned awkward posture as one of the ergonomics principles (Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Kose et al., 2022; Rathore et al., 2022; Sari et al., 2019). According to Kose et al. (2022), there is a link between awkward posture and the risks of injuries. An awkward or prolonged position will enhance stress on body parts and rise with increased flexion, extension, bending, or twisting. Postural risk factors include six key body parts; neck, back, shoulder, arm, wrist, leg, and spine. For instance, forcing arm elevation above a 45-degree angle over time may lead to awkward posture. Fonda and Meneghetti (2022) conducted a case study and discovered that placing and positioning the molding component leads to an awkward upper limb posture. Awkward postures have been recognized as the primary physical risk factor for developing WMSDs.

Brito and Gonçalves (2020) state that awkward postures risk employees' safety and health and reduce the operation's output and efficiency. Awkward postures, according to Brito and Gonçalves (2020) and Brito et al. (2017), lead to worker complaints and absence due to shoulder discomfort and tendinitis. Rathore et al. (2022) assert that ergonomics improvements, such as considering anthropometry when creating ergonomics tools and workstations, might lessen the discomfort associated with awkward working postures. Subsequently, Rathore et al. (2022) advocate reducing ergonomics risk by allowing for enough rest and breaks, limiting the number of hours worked each shift, assigning a medium workload, maintaining a moderate work tempo, and job rotation. In a critical process observation, Afonso et al. (2022) discovered that putting a stacker component weighing more than 50 kg into the device causes the upper limbs into an awkward posture. As a result, a crucial aspect of workplace safety has emerged in response to the increasing number of workplace accidents brought on by awkward postures.

The repetitive movement was mentioned by several previous researchers, such as Afonso et al. (2022), Kose et al. (2022), Rathore et al. (2022), Brito et al. (2017) and Fonda and Meneghetti (2022). According to Afonso et al. (2022), repetitive movements are the main physical risk factor for developing WMSDs issues. An appropriate instrument is recommended to reduce the frequency and length of the effort, hence lowering the degree of risk associated with the repetitive movement. Employees are at varying levels of risk depending on how physically demanding work is. For instance, if a task is repetitious, workers could find it challenging to concentrate (Kose et al., 2022).

Earlier studies found that highly repetitive jobs had a greater ratio of injuries when compared to low-repetition jobs (Fujiwara et al., 2017). According to a case study by Rathore et al. (2022), manufacturing glass art ware required repetitive hand motions during the whole working shift, necessitating specialized equipment and job standards. The risk of developing WMSDs, absenteeism, and productivity issues rises with more repetitive jobs. Musculoskeletal problems affect millions of workers, and repetitive movement significantly worsens costs (Brito et al., 2017). According to Fonda and Meneghetti (2022), ergonomic improvement increases workers' productivity, health and safety, increasing the system's sustainability.

The next ergonomics principle mentioned by previous researchers is manual material handling (Afonso et al., 2022; Brito & Gonçalves, 2020; Kose et al., 2022; Sari et al., 2019; Ulutas, 2011). According to Afonso et al. (2022), one of the primary physical risk factors for the occurrence of WMSDs injuries is handling manual materials. Manual materials handling is any task that involves one or more people moving and maintaining a weight that is dangerous to them, especially the lumbar back area, due to its features or uncomfortable ergonomics conditions. Kose et al. (2022) explained that ergonomics risk assessment for manual material handling systems determined workers exposed to the highest ergonomics risk level. In a case study, Ulutas (2011) claimed that employing more automated material handling equipment can enhance manual material handling by centering the dies, raising the dies by a manually operated jig, and skewing the nuts with a lot of effort.

Several researchers highly mentioned hand-wrist posture as one of the ergonomics principles (Afonso et al., 2022; Fonda & Meneghetti, 2022; Kose et al., 2022; Rathore et al., 2022). Fonda and Meneghetti (2022) identified hand-wrist posture as an ergonomics concept. It was shown that inadequate tool design and work uncertainty were related to a significant risk of hand-wrist injuries. In particular, employing the required tools to perform the assembly in a correct position at the first attempt causes wrist fatigue. Rathore et al. (2022) consider that the ergonomics principle of hand-wrist posture is high risk. In addition to the hand-wrist position, vibration to certain body regions of employees, particularly the hand-arm system when doing manual jobs, contributes to the problem. Kose et al. (2022) highlighted that the risk factors of posture are classified into six categories, with the hand-wrist being one of the ergonomics principles. The reliability of ergonomics risk assessment methods relies heavily on correctly determining joint angles for body components in various postures. According to the case study findings, the tightening procedure has an extremely high-risk level concerning hand-wrist posture.

Brito and Gonçalves (2020), Brito et al. (2017), and Sari et al. (2019) reported that extreme reach is identified as an ergonomics principle among SMEs. Brito and Gonçalves (2020) said that extreme reach was identified as an ergonomics principle to be avoided at all costs. Several ergonomics postures analyses showed that it is hazardous and more likely to result in fatigue and shorter endurance periods (Chaffin, 2002). Extreme reach was seen as a key concern in ergonomics since it increases setup times (Brito et al., 2017). Extreme reaches may harm worker safety, health, productivity, and efficiency (Brito

et al., 2020). Similarly, to this, Sari et al. (2019) claimed that improving extreme reach can improve quality while accelerating the procedure and streamlining work flow.

According to Afonso et al. (2022), based on the systematic observation plan of a critical task, tightening/loosening the parts on the molding machine requires grip strength of the upper limbs. Grip strength is the force applied by the hand to pull on or suspend from objects and is a specific part of hand strength. Several researchers claimed that the repeated task had diminished their grip strength. (Fujiwara et al., 2017). It was discovered that pain and exhaustion were the primary issues facing women in the small-scale industry evaluated by Metgud et al. (2008). The grip strength and fatigue dropped by around 10% by the end of the workday. Decreased handgrip strength values showed that all employees faced general muscle fatigue at the end of the working day, which may be caused by repetitive motion of the working hand. This fatigue was evident regardless of age or duration of exposure (Metgud et al., 2008). According to Rathore et al. (2022), gob-producing and spiral-forming activities at SMEs were classified as high-risk processes requiring prolonged standing for the whole work shift. These tasks require well-designed tools as well as explicit job descriptions. Extra fatigue allowances for prolonged standing activity, length of continuous standing/sitting in the same position, and unbalanced sitting/standing posture should be improved to lessen the danger of prolonged standing.

Lean Principles in SMEs

The result was further analyzed to answer the research question "What are the ergonomics principles, lean principles, and ergonomics assessment methods used by the SMEs manufacturers?" Hence, this section reviews the lean principles used in relation to LE among SMEs. In summary, Table 3 displays the lean principles used by previous researchers.

Table 3

Lean Principles

No	Ergonomics Principles	Count(s)	Literature (s)
1	SMED	6	(Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Fonda & Meneghetti, 2022; Kose et al., 2022; Ulutas, 2011)
2	5S	5	(Brito & Gonçalves, 2020; Brito et al., 2017; Brito et al., 2020; Fonda & Meneghetti, 2022; Sari et al., 2019)
3	Standardized work	5	(Afonso et al., 2022; Brito et al., 2017; Brito et al., 2020; Kose et al., 2022; Ulutas, 2011)
4	Total Productive Maintenance	2	(Brito & Gonçalves, 2020; Kose et al., 2022)
5	Value Stream Mapping	1	(Rathore et al., 2022)
6	Kanban	1	(Brito & Gonçalves, 2020)

Single-minute Exchange of Die (SMED) was mentioned the most by previous researchers as a lean principle used concerning LE among SMEs (Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Fonda & Meneghetti, 2022; Kose et al., 2022; Ulutas, 2011). Manufacturers employ the SMED approach following the LM approach to shorten setup times. Using SMED, manufacturers can improve machine quality and availability while decreasing scrap, rework, and inventory. This approach is based on completing as many setup procedures as feasible while the machine runs and then simplifying the remaining processes by producing a smooth production flow (Kose et al., 2022). The SMED provides faster changeovers, reduced downtime for changing processes, and an impact on the overall equipment effectiveness (OEE) availability factor. Fonda and Meneghetti (2022) employed SMED through four steps in continuous improvement; (1) getting familiar with changeover activity, (2) suggesting possible improvement measures, (3) implementing, and (4) training and control. Ergonomic solutions should be incorporated into setup processes to optimize the benefits of SMED from a human-centric approach. These ergonomics improvements aim to make it simpler for workers to execute their tasks during a changeover by minimizing physical stress and fatigue, which influence total setup time.

Afonso et al. (2022) combined SMED and ergonomics at a metallurgical operation by considering the effects on productivity, adaptability, and worker health management during tool changeover operations. The results showed that the team leader and the operator needed a lot of time to properly perform all the setup activities before the introduction of SMED. Eventually, increasing monthly spring output, reducing setup time by 55%, and offering helpful ergonomics feedback in critical postures, repetitive tasks, and manual handling was feasible. Consequently, the risk levels for each posture in the workplace were lowered, resulting in less exposure to risk factors. According to Brito and Gonçalves (2020), the SMED tool was shown to be successful in reducing setup times, which in turn lowered production batches and lead times.

Moreover, the SMED technique reduces occupational illnesses associated with WMSDs concerns caused by workers' poor posture. In order to shorten setup times and enhance ergonomics conditions, several improvements were carried out using the SMED method and ergonomics analysis. The activities were observed and analyzed using SMED and following the inquiry, a number of improvements were made, reducing the setup time (Brito et al., 2017). Ulutas (2011) used the SMED approach in the study to create an appropriate standard procedure for changeover operations on a specific machine while considering ergonomics and safety concerns.

In relation to the lean principles, 5S was mentioned by previous researchers (Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Fonda & Meneghetti, 2022; Kose et al., 2022; Ulutas, 2011). Fonda and Meneghetti (2022) employed 5S to eliminate confusion and disorder on the shop floor while identifying possible improvements. Moreover, educating a select subset of the workforce, often the most competent workers, on the 5S attitude to infuse more order into the shopfloor will aid in the setup. A tool trolley was used to prevent unnecessary steps when picking up several pieces of equipment. In addition, a specific setup was identified using the 5S approach to maintain the tool trolley arrangement and always in the ready-to-be-used setup. Similarly, according to Brito and Gonçalves (2020) and Brito et al. (2017), the 5S approach was employed to improve productivity and reduce setup time.

Interestingly, Brito et al. (2020) in the study utilized 5S Audits as a step to create the implementation of standards after the improvement. Hence, this shows that the 5S approach can be used for the improvement implementation and sustenance phase. Sari et al. (2019) reported that the efforts to improve work methods are carried out by applying 5S to each operator's work area. The 5S activities of cleaning, sorting objects, labelling, and restricting had been embraced and applied through seiri,

seiton, seiso, seiketsu, and shitsuke. This endeavor aids in eliminating unnecessary movements and processes that do not follow ergonomics principles.

Several researchers mentioned standardized work as lean principles in LE study (Afonso et al., 2022; Brito et al., 2017; Brito et al., 2020; Kose et al., 2022; Ulutas, 2011). According to Kose et al. (2022), using standardized work charts to monitor setup time effectively decreased setup time since this tool assisted operators in standard work while enabling new operators to quickly adapt to the standard technique. As a result, to be considered standardized work, the document must have three important components: takt time, work sequence, and the standard work in progress. According to Alonso et al. (2022), process sequencing was standardized and rearranged throughout the setup operation optimization stage. To reduce operation setup time, the setup operations were standardized. Standardized procedures are, therefore, crucial for keeping track of the improvements that have been implemented. Moreover, standardization helps operators who do setup operations, which helps new worker training.

LM tools, such as standardization, were very important in reducing setup time and improving ergonomics (Brito et al., 2017). Ulutas (2011) asserts that improvement studies and checklists were developed in the last improvement stage. Training is believed to be a crucial factor in ensuring the sustainability of the improvement, and standardized work was used to educate the workers. It should be kept in mind that the key to sustainability necessary for successfully adopting new manufacturing processes is the standardization of that implemented solution.

In addition, total productive maintenance was mentioned by previous researchers related to lean principles (Brito & Gonçalves, 2020; Kose et al., 2022). As part of an autonomous maintenance framework based on operators' daily maintenance responsibilities for their equipment, Kose et al. (2022) suggested that a range of internal activities, such as cleaning, lubricating, and tightening, be shifted to external duties. The implementation of autonomous maintenance reduced setup time, which increased production effectiveness. As a result, minor equipment or quality problems may be avoided without impacting the equipment. Thus, idle time was decreased, making it possible for humans and machines to work simultaneously. Brito and Gonçalves (2020) claimed that TPM was used with LM tools to increase production and decrease setup time.

According to Rathore et al. (2022), value stream mapping (VSM) can be used to demonstrate the possibilities for simultaneously improving operational and workforce performance. VSM is a commonly used LM tool that facilitates identifying value-added and non-value-added processes inside the production system by visualizing information and material flow with symbols, arrows, and indicators. The VSM tool promotes a productive and safe work environment for management and employees. Lowering the risk level score, minimizing lead time, cycle time, scrap, and errors, and increasing overall operational efficiency also aids in enhancing workers'' overall safety workplace.

Kanban is a tool employed to improve productivity and reduce setup time (Brito & Gonçalves, 2020). Kanban is a well-known method for establishing a pull system. It is used to improve material flow throughout the manufacturing and between suppliers and customers (Petrillo et al., 2018). The most significant advantage of employing the kanban system is a direct reduction in manufacturing waste. Kanban method directly supports manufacturers in pursuing the company's current system and enhances inventory movement and management.

Ergonomics Assessment Method

The next sub-section will explain and analyze to answer the research question, "What are the ergonomics principles, lean principles, and ergonomics assessment methods used by the SMEs manufacturers?" Hence, this section reviews the ergonomics assessment method used in relation to LE among SMEs. In summary, Table 4 displays the ergonomics assessment method used by previous researchers.

Table 4

Ergonomics Assessment Method

No	Ergonomics Principles	Count(s)	Literature (s)
1	Rapid Entire Body Assessment (REBA)	4	(Afonso et al., 2022; Brito & Gonçalves, 2020; Brito et al., 2017; Kose et al., 2022)
2	Rapid Upper Limb Assessment (RULA)	1	(Afonso et al., 2022)
3	Human Factors and Ergonomics (HFE)	1	(Rathore et al., 2022)
4	Job Strain Index (JSI)	1	(Afonso et al., 2022)
5	Key Indicator Methods(KIM)	1	(Afonso et al., 2022)
6	Occupational Repetitive Action (OCRA)	1	(Kose et al., 2022)

Based on the review, Kose et al. (2022), Afonso et al. (2022), Brito and Gonçalves (2020), and Ulutas (2011) used rapid entire body assessment (REBA) to assess the level of ergonomics risk. Hignett and McAtamney (2000) described REBA as a requirement identified within the scope of postural analysis tools, particularly concerning sensitivity to dynamic working settings. REBA is a useful tool for evaluating ergonomics, provides a scoring system for muscular activity coming from static, dynamic, rapidly changing, or unstable postures and has been extensively used in previous studies. According to Kose et al. (2022), REBA also provides a quick and easy way to assess the risk of WMSDs in various working positions, regardless of whether muscle activity is static, dynamic, rapidly changing, or unstable. It offers a technique for rating it across the entire body and is divided into sections that may each be graded separately based on movement planes. Using the pen-and-paper approach, REBA offers an action level with a symbol of importance and requires minimal equipment (Brito & Gonçalves, 2020; Ulutas, 2011).

Rapid Upper Limb Assessment (RULA) is a tool for measuring ergonomics assessment methods and was used by Afonso et al. (2022) in their research. RULA was specifically employed for manual material handling when it came to posture. In the case study, the hazard associated with manual material handling was avoided by adopting a crane to handle components. RULA is a quick posture analysis observational method.

It is a subjective observation-based posture analysis approach highlighting the upper and lower body. It employs several illustrations depicting various body postures. RULA was developed as a screening tool for people exposed to risk factors for upper limb disorders at work. It considers the possibility of repetitive movement and force required in a task. It was designed to be conducted quickly, with minimum equipment or disruption to the working environment, and with the least inconvenience to individuals being observed. It needs no prior experience with observation techniques, is simple to learn, and has been proven accurate (Dockrell et al., 2012).

Rathore et al. (2022) used Human Factors and Ergonomics (HFE) as a tool for the ergonomics assessment method. The engineering, design, technology, science, and management discipline of HFE, which focuses on human-machine interaction, is concerned with human-compatible systems. In the case study, HFE was used to measure the risk in the glass art ware industry, measured in four HFE categories, namely; (1) physical factors: repetitive task, working posture, forceful exertion, and vibration, (2) psychosocial factors: job satisfaction, mental workload, job stress, and psychological strain, (3) managerial factors: reduction of resources, supervisor support, communication system, and co-workers support, and (4) work design factors: job rotation, job clarity, task design, and job autonomy.

To assess the risk factors that cause WMSDs in the upper extremity, the job strain index (JSI) was used by Afonso et al. (2022) to identify the critical task concerning repetitive movement. The upper-body pain risk is assessed using the JSI technique on repeated activities to identify the risk factors contributing to WMSDs. JSI approach is based on physiologic, biomechanical, and epidemiological considerations and was introduced by Steven Moore and Garg (1995) with six ergonomics risk variables, including the intensity of exertion, length of exertion, efforts/minutes, the pace of labor per day, and hand/wrist posture which are each multiplied by each parameter. Each variable has five categorization levels, which enables the observer to identify risk factors (Mohammadpour et al., 2018).

Afonso et al. (2022) employ Key Indicator Methodologies (KIM) to investigate the risk factors associated with manual material handling procedures. Various evaluation methodologies have been used to determine the risk of WMSDs associated with the procedure. KIM was created to detect and analyze the risks associated with manual handling, job characteristics, and their interaction. There are several key indicators to be considered in the KIM, namely; (1) duration of manual job operations daily, (2) type, length, and frequency of the forces that execute, (3) body position when performing manual tasks, (4) hand-arm position when performing manual tasks, (5) work organization, and (6) work conditions. The key indicators are categorized according to several scales that reflect actual conditions and range from a minimum to a maximum (Klussmann et al., 2010).

Kose et al. (2022) identified overall posture with the work element of frequency, duration, regularity, and recovery period using Occupational Repetitive Action (OCRA). OCRA is the most appropriate method for identifying problems in repetitive occupational action. Using the OCRA checklist, the primary risk of the upper body was identified, and its effects were categorized. Based on the OCRA index results, the checklist was recommended for workstations with many repetitive operations. The color designations for green, yellow, and red were created using the OCRA checklist, in which green represents no risk at the station, indicating that more investigation is unnecessary. Meanwhile, yellow signified the edge risk, while red represented the highest risk (Trianasari et al., 2019).

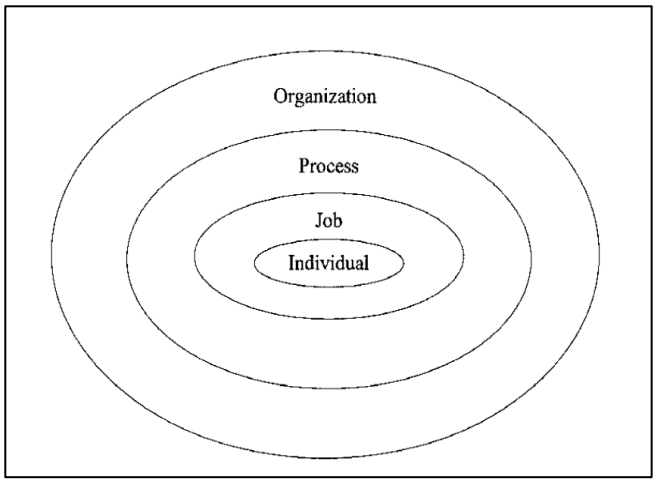
Kose et al. (2022) evaluate the risk factors by emphasizing the back, shoulder, neck, and arm with load weight, duration, and frequency using Quick Exposure Check (QEC). It was created for OSH practitioners to use to assess exposure to risk factors for WMSDs and provide a foundation for

ergonomics intervention in the workplace. The tool is based on the demands of practitioners and cutting-edge research findings. The tool has a high degree of sensitivity and accessibility and a generally acceptable level of reliability. Research further shows that the tool is dependable and useful for a wide range of operations jobs. Assessment can usually be completed in 10 minutes for each activity with a brief training time and less practice (Li and Buckle 1998).

Afonso et al. (2022) assess the risk factors through Shoaf's Model related to manual materials handling. Shoaf et al. (2004) developed a methodology for assessing organizational health that takes a comprehensive approach to work aspects at the individual, job, process, and organizational levels. The relationship between the individual, job and organizational orientations that drive organizational health is depicted in Figure 4. These three orientations can be used to categorize work improvement strategies. Since categories are likely to overlap, the strategy boundaries are unclear. The large circle organization restrict the smaller circles, which are individual, job, and process. Therefore, the action in the bigger circle has a broader scope and influences the intervention in the smaller circle. Organizational interventions such as restructuring a production area into an independent work group can affect the scope of a job and the individual's responsibility.

Figure 4

Shoaf's Model

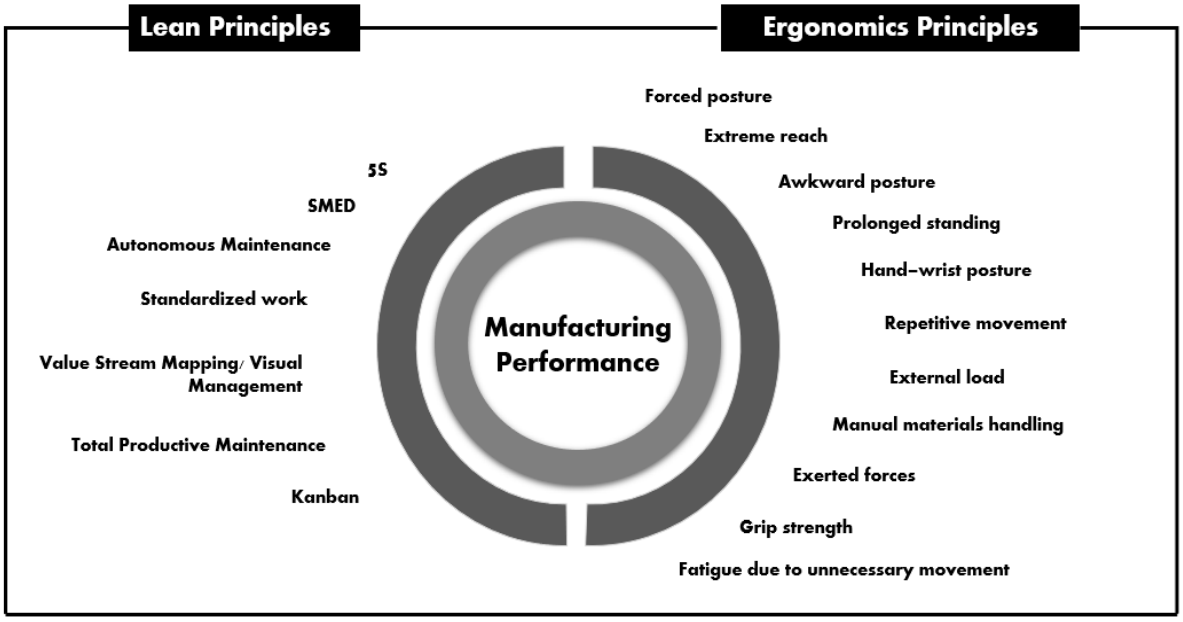


Organizations are employing the idea of LM more often to meet customer requirements and promote employee well-being. The health of human resources must be assessed and evaluated regularly. By decreasing waste, LM aims to increase output while lowering costs. Workers must provide input, participate immediately in the improvement, and help each other to decrease stress in LM. When viewed via LM, the ergonomics viewpoint is a significant industrial risk that may impair competitiveness due to labor expenditures, labor income, absenteeism, low quality, and lower production costs. Presently, most organizations rely only on LM and do not consider worker safety.

Due to repeated movements or high workloads, WMSDs are prevalent occupational diseases among assembly workers. Integrating ergonomics concepts into the LM process is critical to the effective implementation of the LM implementation. Figure 5 visualizes the integration of lean and ergonomics principles to holistically and sustainably increase productivity while maintaining employee health and performance.

Figure 5

Lean and Ergonomics Integration



Ergonomics is also essential in easing setup tasks, speeding up change over time, and providing a safer working environment (Fonda & Meneghetti, 2022). A poorly designed ergonomics manufacturing setup can result in worker accidents, defective products, capacity limitations, and low profit (Kose et al., 2022). Brito and Gonçalves (2020) suggested that manufacturers apply ergonomics evaluation in combination with LM initiatives to overcome these production-related challenges. Rathore et al. (2022) assert that the simultaneous application of the lean and human factor paradigms is a practical, useful, and efficient method for enhancing the productivity of SMEs. For instance, the VSM tool will significantly minimize LM and ergonomics wastes like motion, waiting, and defect waste throughout the value chain. It helps raise operational risk while improving operational efficiency by shortening the lead time (Brito & Gonçalves, 2020).

Ergonomics may be the basis for lean transformation by reducing waste, and LM can reduce ergonomics risk (Brito et al., 2020). Effective ergonomics may enhance workstation design and layout, increase productivity, and prevent workplace accidents. Ergonomics intervention may also be considered to lower waste of motion while reducing ergonomics risk factors. Waste ergonomic motions, such as stretching, bending, awkward postures, and excessive reaching, can severely influence worker safety, health, productivity, and efficiency (Brito et al., 2020). LE eliminates activities and processes that do not adhere to ergonomics principles. The relationship between LM and ergonomics is found in human effort, worker autonomy, the risk of WMSDs, and worker participation or involvement.

Employees feel that the ergonomics function of the human element and working conditions are critical for improving workstations and that their implementation may strengthen the firm's interaction with their workers (Sari et al., 2019). It is critical to consider productivity in operation; nevertheless, more repetitive tasks contribute to WMSDs, increased absenteeism, and decreased productivity. Brito et al. (2017) demonstrated that the level of WMSDs decreased, demonstrating that improvements in LM activities aid in productivity and ergonomics improvement. Afonso et al. (2022) showed in a

metallurgical industry study that incorporating ergonomics into LM operations reduces expenses related to workers' health concerns. As such, ergonomics may be a powerful driver for initiating a LM transformation, which might lead to a decrease in ergonomics risk. Some of the negative consequences of LM on workers' quality of life are reduced through LE workplace strategies.

CONCLUSION

Many industries saw LM as a potential means of meeting customer demand and fostering a safe workplace culture by improving operational and worker performance. The focus of social aspects is on human interactions, whereas the focus of technical aspects is on operational process factors. However, when implementing LM, the industry usually ignores the social aspect and focuses only on the technical aspect of improving operational performance. This ignorance may impact the employee's health and safety at work.

In light of this, the ergonomics principles in SMEs LE include awkward posture, repetitive movement, manual material handling, hand-wrist posture, excessive reach, grip strength, and prolonged standing. Due to these findings, future researchers in the same field could adapt to use this set of ergonomics principles in their work. Furthermore, manufacturing practitioners may gain from this research by using ergonomics principles to plan their next steps for improving social aspects of human relations and enhancing operational performance. The pressure on body parts increases with greater flexion, extension, bending, or twisting, which is why awkward posture, which was frequently highlighted, can increase the risk of injury. In addition, highly repetitive jobs have a higher injury ratio than low repetition jobs (Fujiwara et al., 2017). The primary physical risk factors for musculoskeletal injuries include manual materials handling which refers to any job that requires one or more people to move and support a weight that poses hazards to them, notably the lumbar back area, due to its characteristics or poor ergonomics conditions.

Moreover, it can be concluded that SMED, 5S, standardized work, total productive maintenance, value stream mapping, and kanban are lean principles that practitioners may apply to increase their performance and benefit ergonomics. SMED, 5S, and standardized work were particularly used by researchers investigating SMEs LE. The SMED tool helps decrease setup times during equipment changeover. It is required since this approach demands a lot of effort, which raises the risk of WMSDs. The 5S approach may be an effective tool to reduce unnecessary movements and systems that do not adhere to ergonomics principles. Moreover, 5S may implement standards after improvement through 5S Audits. On the other hand, standardized work is meant to train workers. Long-term solutions are required to successfully implement new production processes, and standardization is the key to long-term solutions.

Another important aspect of this review is the ergonomics assessment method. The researchers employed several assessment methods based on the review to determine the ergonomics risk. Yet, it was interesting to discover that the previous researcher frequently used REBA. This interest in using REBA is because it gives a score system for muscle activity resulting from static, dynamic, rapidly changing, or unstable postures, which fits well into ergonomics evaluation. According to Kose et al. (2022), REBA provides a quick and simple measure for evaluating a variety of working postures for the risk of WMSDs and divides the body into areas to be coded independently, in accordance with movement planes, and provides a scoring system for muscle activity across the entire body, whether it is stagnant, dynamic, fast-changing, or unsteady. Most researchers employ the REBA approach because

of this, unlike other assessment tools, such as RULA, which was designed solely for posture, JSI for repetitive movements, and KIM and Shoaf's model for manual material handling.

LE is the holistic and long-term consideration and pursuit of ergonomics and LM to maximize productivity while sustaining employee health and performance. Ergonomics may serve as the foundation for lean transformation by reducing waste, and LM can reduce ergonomics risk (Brito et al., 2020). Employees believed that the ergonomics function of the human element and working conditions in LM is critical for improving workspaces and that its implementation may be more advantageous to the employee-company relationship (Sari et al., 2019). This study, however, has several drawbacks. Despite Gusenbauer and Haddaway (2020) assertion that there are 14 databases with the capacity to search for possible publications, only two databases, WoS and Scopus, were used in this review. Second, this review extended the research keywords based on previous research and synonyms. Yet, there was a chance that more keywords may be included to improve the article search. As a result, future studies might overcome this constraint by broadening the existing terms.

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