The Effect of Ergonomics in an Assembly Line System's Work Environment - A Literature Study

Bachelor's thesis, 15 credits
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Abstract

The purpose of this literature study is to explore the most important ergonomic factors that play a role in shaping the work environment of assembly line systems. Since the subject of ergonomics in production systems has continuously gained great interest in the past years, it was decided to conduct research around this topic. The literature study type was chosen to answer the research questions. This was done because even though various articles discuss the mentioned areas, they usually still have a specific focus. For example, human errors, automation, simulation, virtual reality etc. Therefore, it was decided to carry on with a more comprehensive review that takes into account the most important ergonomic factors in general and how they influence assembly workstations both positively and negatively. Thus, two research questions were explored:

Research question: *What are the most important ergonomic factors that influence an assembly line system's work environment?*
Sub-research question: *What are the positive and negative effects and what causes them?*

In order to proceed with the study, a systematic literature review and thematic analysis were conducted through the use of secondary data only. This was done by searching for different articles through two academic databases; ScienceDirect and Scopus. Lastly, the words that were used to search for articles were highly relevant in terms of the research questions.

In regards to the analysis and conclusion, different factors were found including automation and cobots, job rotation, the implementation of human factors, and repetitive manual tasks. The results showed that all these factors can affect an assembly line system's work environment to a great extent, both positively and negatively. First of all, cobots contribute by helping human operators with difficult tasks, yet, the collaboration of humans and robots is viewed as risky to some extent. Furthermore, the level of the implementation of ergonomics at work places is crucial to provide a healthy work environment. Ultimately, repetitive tasks can have a great impact on workers and thereby the whole work environment becomes affected. Therefore, convenient training sessions are highly important to ensure safety in such cases.

Keywords: Ergonomics, human factors, assembly lines, work environment automation, job rotation.

Summary

Syftet med denna litteraturstudie är att undersöka de viktigaste ergonomiska faktorerna som spelar roll för att forma arbetsmiljön i löpande bandsystem. Eftersom intresset för ämnet ergonomi i produktionssystem har ökat kontinuerligt under de senaste åren, valde man att forska kring detta ämne. En litteraturstudie valdes för att kunna besvara forskningsfrågorna. Även om olika artiklar diskuterar de valda områdena, så har de oftast ett specifikt fokus, till exempel, mänskliga fel, automatisering, simulering, virtuell verklighet osv. Därav valde man att fortsätta med en mer omfattande genomgång som tar hänsyn till de viktigaste ergonomiska faktorerna i allmänhet och hur de påverkar monteringsplatser både positivt samt negativt. Därför undersöktes två forskningsfrågor.

Forskningsfrågor:
Vilka är de viktigaste ergonomiska faktorerna som påverkar arbetsmiljön i ett löpande bandsystem.
Delforskningsfråga: Vilka är de positiva och negativa effekterna och vad orsakar de?

För att kunna gå vidare med studien genomfördes en systematisk litteraturgenomgång och en tematisk analys, endast genom användningen av sekundära data. Detta utfördes genom att söka efter olika artiklar i två akademiska databaser; ScienceDirect och Scopus. Orden som användes vid sökningen av artiklarna var mycket relevanta för forskningsfrågorna.

I slutsatsen och analysen hittades olika faktorer så som automatisering och cobots, jobb rotation, implementering av mänskliga faktorer och repetitiva manuella uppgifter. Resultaten visade att alla dessa faktorer kan i stor utsträckning påverka arbetsmiljön i ett löpande bandsystem, både positivt och negativt. Först och främst bidrar cobots genom att hjälpa mänskliga operatörer med svåra uppgifter, ändå ses samarbetet mellan människor och robotar till viss del riskabelt. Dessutom är nivån på implementeringen av ergonomi på arbetsplatser avgörande för att bidra till en hälsosam arbetsmiljö. I slutändan kan repetitiva uppgifter ha stor inverkan på arbetarna och därigenom påverkas hela arbetsmiljön. Därför är bekväma träningspass mycket viktiga för att garantera säkerheten i sådana fall.

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Abbreviations

HF - Human Factors

HRC - Human-robot collaboration

IDT - School of Innovation, Design and Engineering

MDU - Mälardalen University

MSD - Musculo-skeletal disorders

WHO - World Health Organization

1. Introduction

This chapter presents the background of the project. The problem formulation is described, followed by the aim of the study and research question/s.

1.1 Background

The competition for businesses is becoming more intense nowadays, and therefore, more competitors are trying to satisfy their customers. In the industry world, the need for different products is increasing and the companies thereby must meet the demand. As demands increase, companies need to produce more products than usual and at the same time, consider workers' comfort and health. There are several factors that need to be considered, such as workplace design in order to improve productivity. These factors are needed to protect employees from health problems and accidents which can take place during working hours. Therefore, the workplaces must be designed according to ergonomic aspects (Anghel et al., 2019). The aim of ergonomics is to achieve an optimal relationship between the employees and their working environment. Two major conflicting factors must be considered to be able to reach this optimum point. On the one hand, managers and companies require the highest levels of efficiency and productivity, and on the other hand, employees need comfortable and safe workplaces that ensure their health and physical well-being (Battini et al., 2020).

Assembly lines consume most of the investment capital and make up the majority of the company's workforce. Assembly line workers are easily exposed to work-related musculoskeletal disorders (MSDs) and ergonomic problems. Inadequate workload distribution can reduce assembly line performance, because MSDs and injuries have a significant impact on workers, the economics of the production system, and increase the cost of worker compensation and absenteeism. In addition, ergonomic issues and MSDs affect product quality and reduce productivity. Even though advances in workplaces' safety and ergonomics have been observed over the last few decades, workers are still exposed to work-related MSDs and other injuries. The MSDs can be prevented, depending on how risk factors are identified and controlled in the workplace and how well ergonomic choices are applied. According to studies, MSDs can lead to lower productivity due to higher error rates, injury rates, and absenteeism. Ergonomics indicates the design of efficient, productive, profitable, and safe production systems for

employees, both performance and human health are essential to the design of sustainable manufacturing systems (Abdous et al., 2022).

According to Otto & Battaïa (2017), various risks can be prevented by improving workplace ergonomics. In recent years, scientists and experts have focused on this issue by including strategies and approaches, to improve employees' well-being and safety. This is done by considering the ergonomic features of production systems with an emphasis on manual assembly systems.

Research on the topic of ergonomics in production systems has been continuously receiving high interest. Therefore, previous research papers between the years 2015-2021, are explored in order to take a look at how ergonomics affect assembly lines. It is preferable that the reviews would not be older than 2015, since new technologies and developments take place all the time. One of the articles is a literature review by Cardoso et al. (2021) that investigates how automation can improve work conditions. It argues that robots supporting human beings at workstations contribute to ergonomics (Cardoso et al., 2021). Similarly, discusses that robots can, to a great extent, minimize different ergonomics problems and thus provide more safety and higher productivity (Colim et al., 2020). In addition, since automation is taking a great place in production systems nowadays, another article was studied that discusses the importance of safety when operators and robots work together. This is referred to as “collaborative operations" where the article emphasizes on the importance of taking safety measures (Gopinath & Johansen, 2018). In Battini et al. (2017), it is argued that combining the assembly line balancing with parts feeding is crucial, from an ergonomic point of view. Following the subject of assembly line balancing, Battini et al. (2015) also addresses this problem, however, from an ergonomic aspect using “Predetermined Motion Energy System", a “multi-objective approach”. Moreover, previous research that is similar to the focus of this paper is found in Bergman et al. (2021), where the authors study assembly workers' understanding of cognitive performances. While the article explores the area of ergonomics and its effect on assembly workers, it does not quite cover all the ergonomical essential factors. Finco et al (2020), on the other hand, presents a mathematical model in order to reduce the cycle time, as well as a linear sequencing model that aims to reduce the physical work-overload of workers. There are other papers that focus on production systems’ errors where the focus is set on assembly lines and the possible errors that are a result of operators. Here, the ergonomic aspects are not covered as much and the whole focus lies on the quality, flexibility, human errors etc. (Torres et al., 2021). Furthermore, in Diego-Mas et al. (2020), the authors argue that ergonomics risks can be prevented using virtual reality. However, the paper’s full focus is set on immersive media which is a specific area. The last article which was explored, is about an evaluation of how a workplace is designed as well as ergonomics, through simulation. It basically discusses that it is possible to

prevent all ergonomic risks during the design phase (Caputo et al., 2019). Although various reviews from years 2015–2021 can be found about ergonomics in production systems, which many of them are listed above, there are not enough comprehensive literature reviews which discuss the different ergonomic factors that affect a production work environment of assembly lines.

1.2 Problem formulation

With the massive implementation of assembly line production systems nowadays, more ergonomic factors are being considered to ensure the safety of workers and their well-being in all work environments (Dalle Mura & Dini, 2021). However, these different factors can, to a great extent, affect work environments and production systems both positively and negatively. On the one hand, the topic of ergonomics is usually discussed in articles in order to make different production systems a better place for employees. These articles usually focus on specific topics such as human errors, automation, simulation, virtual reality or specific ergonomical areas as mentioned in the background. Yet, there are not many literature reviews that discuss the most important ergonomic factors and how they influence assembly workstations, workers and production whether positively or negatively. Therefore, a more comprehensive review that considers the major ergonomic advantages and disadvantages in assembly lines' work environment is needed.

1.3 Aim and Research Questions

This research aims to develop knowledge about ergonomic factors that influence an assembly line system's work environment, positively and negatively, through a literature study.

In order to reach the goals above, the following research question and its sub-question will be answered in this paper: *What are the most important ergonomic factors that influence an assembly line system's work environment?*
Sub-question:

What are the positive and negative effects and what causes them?

1.4 Limitations

There are some limitations to this study. Firstly, instead of covering every possible ergonomic factor and examining their effects in detail, this thesis aims to explore different ergonomic factors and the way they affect a work environment generally. Moreover, due to the breadth of the subject of ergonomics and human factors, this paper will be limited to explore some specific parts, that is, mainly ergonomics' factors that have the greatest impact on an assembly lines' work environment nowadays, which are considered essential in a production environment.

2. Research methodology

In this chapter of the paper, the research methods used are described and explained. This includes the literature study approach, the qualitative method, as well as some specific methods such as snow bowling.

2.1 Research approach

Before starting to write the thesis, it was required to send a registration form to the examiner, which states the topic chosen and a short description of what the project will examine. In order to fill the registration form, a short research was conducted on the topics that the students were interested in, namely ergonomics and production systems. Thereafter, once the thesis topic was accepted, a supervisor was chosen. The next step was to hold a meeting with the supervisor where the topic, the research questions and the aim of the project were discussed, and a time plan was made. After the first meeting, massive reading was performed by the two students which led to a considerable amount of data collection about ergonomics, production systems, assembly line, and work environment. This allowed the students to form a clear background to the thesis and thereby a theoretical framework was written. The following step was to write the results of the literature study which includes the most important ergonomic factors that influence an assembly line system's work environment negatively and positively. The results part was written by studying various articles in order to present the factors. Regarding the discussion and analysis of the paper, they were performed by analyzing the results of the study along with the use of the theoretical framework's information. This finally led to the answers of the research questions. Lastly, the study as a whole was summarized in the conclusion and some recommendations were mentioned.

2.2 Systematic literature review

A systematic literature review is a literature approach which usually has to answer a specific research question or questions. Therefore, an indepth research of various articles is conducted when writing a systematic literature review. This type of review is considered to be more structured in contrast to a narrative literature review. Here, articles are usually reviewed less thoroughly and are then summarized (Green et al., 2006). In addition, a systematic review must have a solid methodology and structure in order to collect and arrange the data properly (Faggion et al., 2017). The main goal of this type of review is to identify and study all the empirical evidence needed, which will lead to the answers of the proposed question (Snyder, 2019).

In the beginning of this study, a more narrative-like review was conducted with the purpose of understanding the different topics of the thesis. A narrative literature review often studies other articles with the purpose of finding how a particular area has progressed or developed through the years and across different traditions (Snyder, 2019). Later, a systematic literature review was adopted to write this thesis since specific areas were chosen and a research question was proposed. This approach will allow a more detailed research to answer the particular questions presented earlier.

How is a review conducted?
Usually, many articles are read with focus on abstract and introduction in order to identify the relevant and interesting articles and thereby, when the articles are chosen, more comprehensive reading is performed.

2.3 Data collection method

Data is the collective raw fact that is necessary to constitute a research work. There are two types of data, primary data, and secondary data. Primary data is data collected directly from the respondents. Primary data need to be analyzed by the researcher to report a result. The researcher obtains data through surveys or fieldwork. Secondary data is the data that is already available for use by others. Such as data sources, books, published journals, research work, etc. (Habib et al., 2014).

The data collection method was used in this study, although only secondary data was collected. This project was completed using a systematic literature review approach and therefore the focus was primarily on secondary data. Secondary data was collected from relevant peer-reviewed articles and conference papers. Conference papers were also included in this study since they serve the purpose. Articles were found through databases such as ScienceDirect and Scopus. The search engine Google Scholar at MDU's electronic library was used in the beginning as well as Primo, with the purpose of having a wider research area to read from. The keywords that were used are ergonomics, human factors, assembly-line systems, work environment, research methods, etc. In addition, the reviewed articles are published between 2015 and 2021.

2.3.1 Secondary data

Since the research conducted in this paper is a literature review, only secondary analysis of earlier works was performed. According to Bryman & Bell, (2015): "Typically, secondary data analysis entails the analysis of data that others have collected".

When carrying a project, it is usually less time-consuming to rely on secondary data that are of high quality. This works well when a literature review is carried out. On the other hand, there are always some disadvantages when working with secondary data. These limitations include complex data which makes it harder to find particular information. Also, the review of these data might lead to new interpretations that were not taken into account by the original writers. Lastly, even though secondary data contains and often requires high quality data, it is still not possible to control all the data in different databases (Bryman & Bell, 2015).

2.3.2 Forward snowballing

Forward snowballing is a strategy that is used during the collection of data. Forward snowballing is a strategy that is used to identify articles based on the citations in the examined article. The selected citation is then searched through a database. After that, the article is read through, and it is determined whether the information in the article is relevant and useful for the study (Wohlin, 2014). Each article that came into use, was redirected to a different similar article. In this way, relevant information was collected from various articles and was used in this study.

2.4 Data analysis method

Thematic analysis is a common method used in qualitative studies that are used for the purpose of “identifying, analyzing, and interpreting patterns of meaning” (Clarke & Braun, 2016). The analysis has been conducted through the phases of the thematic *analysis which is a developing, reiterative, and reflective process.* The phases are divided into six steps: *1. Get familiar with the data. 2. Generate codes. 3. Search for themes. 4. Review the themes. 5. Define and name the themes. 6. Produce the report.* Although it is a “six steps process”, it involves moving back and forward between the phases (Nowell et al., 2017).

In the review of the collected material, thematic analysis was used. The data were organized into different themes depending on the similarities and differences that could be identified. Later, each theme was coded with a color, to facilitate the organization and identification of the data set. The different themes were organized only according to the research questions they are relevant to, for example, if the data were relevant to positive or negative effects/factors. Thereafter, each theme was organized into respective sub-themes. In terms of the factors that influence either positively or negatively, the factors that are considered to contribute to the health and energy of workers as well as the overall effectiveness of organizations are identified as “positive”.

Whereas, the factors that could result in harm, injuries and stress for workers as well as less productivity and more costs for companies are identified as negative. Moreover, regarding the most important factors, the ones that have a great impact on employees firstly and on the whole organizations' performance secondly, were chosen. When it comes to the importance level, the factors that affect the employees and the company to the greatest extent of all were selected and discussed in the analysis. In other words, the ones that have the largest contribution in shaping a work environment.

Firstly, a quite general search through databases such as ScienceDirect and Scopus was conducted, in order to see what type of articles is going to come up. The words that were searched for were, ergonomics, assembly line systems and production systems. Since the results were enormous, it was decided to add more words such as the ones shown in Table 1 below, which were: ergonomics and assembly line problems, ergonomics and production systems, ergonomics and human factors (HF), etc. Out of the many articles that were found, the first few hundred articles' titles were read and the ones that included a related title to the keywords were viewed. In the review process, the abstract and the introduction were read at first as shown in Table 2. This was done in order to decide if the article should be included in the literature review or not depending on whether the topics are suitable for the research. Afterwards, the results and analysis of the suitable article were viewed and read. At last, a total of 26 articles were used in order to answer the research questions to complete this paper.

Databases: ScienceDirect & Scopus	**Search terms**
#1	Ergonomics and assembly line systems
#2	Ergonomics and production systems
#3	Ergonomics and work environment
#4	Ergonomics and human factord
#5	Ergonomics and assembly line problems

Table 1: table shows the words were searched for

	Number of papers
Title	558
Abstract	295
Paper	26

Table 2: down selection of the number of papers

By reading the titles of 558 papers, we down-selected 295 articles that were most relevant to read their abstracts. By further reading and the use of forward snowballing, 26 papers were used for the results as shown in Table 3.

2.5 Quality of study

Reliability, validity, and generalizability are known to be the three general criteria that are used to assure the quality of data, research methodology, and accuracy of the study results. These principles are important both in qualitative researchers as well as in quantitative researchers (Adams et al., 2014). In the following part, two of the principles and how they are applied in this paper are explained below in order to achieve the highest quality of the study.

2.5.1 Reliability

Reliability is the question of whether the results of the study are reproducible. The term is often used in connection with the issue of consistency in measures developed for business and management concepts (teamwork, employee motivation, organizational efficiency, etc.). It is primarily about consistency. In other words, if the result is always the same no matter how many times you measure it, you can say that the measuring instrument is reliable. That is, if the results of the measurement process are reproducible, the instrument is reliable – that does not mean it is valid! (Adams et al., 2014).

In this study, the selected sources, such as articles, have been verified and ensured that all information matches the sources. In order to achieve reliability for this dissertation, consistent measurement of the collected data has thus been made.

2.5.2 Validity

Validity refers to the strength of our conclusions or statements. It's about whether you measure what you should and how accurately you measure. Validity contains two parts: internal validity and external validity (Adams et al., 2014).

Internal validity is about the probability that changes in the dependent variable (substance) can only be ascribed to manipulation of the independent variable and can not be ascribed to any other variable. In this case, one speaks of a high internal validity in a study. A study has a low internal validity if an alternative explanation can be given to the result of the study. External validity is about the degree to which a result can be

generalized to other environments and the situation. While conducting an experiment, the researcher hopes that the future results can later be applied to other populations in other geographical locations (Adams et al., 2014).

A certain degree of accuracy must be achieved to support the validity of the dissertation. Therefore, the search results of the selected data were analyzed and the most relevant of the collected data were selected for further use during this thesis. The relevant academic articles, as well as the books, were carefully reviewed, and the most useful parts were collected for use in this study.

3. Theoretical framework

In this chapter, all the needed theories to conduct the research area are covered, as well as all the information and facts needed in order to present the results later.

3.1 Ergonomics

Ergonomics is defined as a study of science application to make the aspects of a work environment suitable to different groups of people. This applies to people with various flexibility abilities, lengths, strengths and skills (Makhbul, 2013). Humans are considered to have the ability to be flexible, innovative and creative which are still challenges to robots for example that only have limited abilities. Nonetheless, the human body could easily be hurt or injured due to overloaded physical work and thus develop musculo-skeletal disorders (Berlin & Adams, 2017). MSD are defined as “A disorder of the muscles, tendons, peripheral nerves or vascular system not directly resulting from an acute or instantaneous event (e.g., slips or falls)” by the World Health Organization (WHO). In addition, if the work environment results in one of these disorders, then it would be considered a significant cause (Karthikeyan et al., 2022). Therefore, the main goal of the ergonomics field is to ensure safety and to provide well-being to workers and employees (Karltun et al., 2017).

In addition, ergonomics is a crucial discipline that should be taken into account when designing a workplace (Shell et al., 2012). The integration of ergonomics in a workplace could result in a balance between different work tasks and the characteristics and abilities of workers. As a result, healthier work environments and higher productivity will be achieved. This further means that it could be to a great extent, an indication of employees’ loyalty towards the organization they work in. On the other hand, if a workplace is designed poorly, anxiety, stress and a decrease in productivity will be spread out between workers (Makhbul, 2013).

3.1.1 Types of ergonomics

The three main sides of ergonomics which are equally important to consider in work design are the physical, cognitive and organizational ergonomics (Berlin & Adams, 2017). The first type is physical ergonomics, which is in regards to the human body and anatomy as well as the physiological parts of a human being. Its main goal is to reduce the workload that relates to any physical activities performed by employees (Cardoso et al., 2021).

The second type is cognitive ergonomics which concerns itself with the mental aspects of human beings. These aspects include: decision making, reasoning, memorizing human-computer interaction, work stress, reliability, etc (Cardoso et al., 2021). Even though humans are preferred by organizations to perform the work (as mentioned earlier), since they have unlimited abilities compared to robots, they could still be faced with issues related to their abilities to think, learn and process. Making decisions that could result in undesired consequences, misinterpreting received information or making simple mistakes are examples of these issues (Berlin & Adams, 2017). Therefore, it is crucial to consider and implement cognitive ergonomics when designing a workplace.

Finally, the third type, organizational ergonomics that came in the beginning of 1980s. It was when researchers realized the importance of relationships between different groups of people within organizations. This type of ergonomics focuses highly on the stakeholders that surround ergonomics. Here, it is crucial to know that organizations differ from each other in many aspects and thereby, each company has to pay attention and raise awareness about its own needs. These social factors include geographical location, culture, size, history etc. (Berlin & Adams, 2017).

3.2 Production system

A production system can be defined as a socio-technical system that transforms inputs into desired outputs in a value-added or related process. Therefore, the goal is to produce a final or intermediate product. A certain sequence of several transformations is represented by the internal structure and system management of processes, which are determined by the organizational structure and organization of processes (Schumacher et al., 2020).

3.2.1 Assembly line

There are many types of production systems, one of them is the assembly line system. A typical assembly line system consists of multiple workstations, each performing a specific set of tasks. Products move sequentially from one workstation to the next. Dividing the entire task set into subsets, each executed at a specific workstation, allows for specialization at each workstation. The tasks can be performed manually or by special equipment to achieve high efficiency (Bukchin & Tzur, 2000).

The assembly line system is considered crucial to a country’s sustainable development and the growth of its economy since it is one the most important manufacturing systems (Biazen & Gebeyehu, 2019). Therefore, in order for an assembly line system to become flexible and reusable, it should keep pace with the development of different manufacturing systems and the constantly changing requirements of production (Krüger

et al., 2017). The main goal of assembly workstations is to guarantee the needed rate of productivity which meets the customers' demands. However, it is highly important to take into account the safety and well-being of operators who work at these assembly workstations (Berlin & Adams, 2017).

3.3 Work environment

Work environment defines everything that affects a person at work, which includes both the physical environment and the psychosocial environment. Even though not all people react in the same way to a certain condition, there are identifiable factors in a work environment that stand in the way of people's needs (Lenneer-Axelson & Thylefors, 2005).

From a holistic perspective, the work environment is divided into different parts: *the physical*, *the organizational* and *the social*. The *physical* part refers to the material conditions such as premises, tools, machines, and other work tools. That is, the objective, that which is observable and measurable. The *organizational* part deals with the division of work, the decision-making mandate and the formal conditions that regulate employment conditions. The *social* part refers to the relationships that concern relationships, interactions and communication between people and groups (Lenneer-Axelson & Thylefors, 2005).

3.4 Automation and human-robot collaboration

Automation is simply explained as a replacement of human labor with different new developed technologies in order to complete the more challenging tasks that human operators struggle to perform. It can be resembled in various examples such as industrial robots, computer machinery, artificial intelligence, human-robot collaboration (HRC) etc. Nowadays, these technologies are being increased and developed rapidly (Acemoglu & Restrepo, 2019). Moreover, different organizations have been gaining massive interest in HRC, since manufacturing companies' conventional ways of production are being changed continuously (Mohammadi Amin et al., 2020).

3.4.5 Collaborative robots (Cobots)

Nowadays, the idea of developing a robot that can work and interact with human beings, has become highly attractive. This is because cobots are being made to support human operators by performing the more complicated tasks with the goal of making the

tasks easier for workers. However, human safety should be considered to the greatest extent possible (Mohammadi Amin et al., 2020).

3.5 Job Rotation

Job rotation is a strategy that is used in organizations with the aim of sequencing jobs between workers. With job rotation, the workers are rotated between different tasks in order to prevent themselves from spending a long time at one workstation and working with the same task. In addition, work efficiency can be achieved with the help of a job rotation schedule. A rotation schedule is designed regarding different criteria such as workload levels, workers' characteristics, skills, qualifications, etc. Job rotation can be determined by both managers and superiors but also by the workers themselves (Asensio-Cuesta et al., 2019).

4. Results

The results chapter represents the results of this study with the focus on answering the research questions.

4.1 Articles and the year of publication

The search for information was concluded with 26 articles at last. The articles were from the years 2015 to 2021 to avoid any information that might be inapplicable to some extent. The figure 1, below, illustrates the number of articles in relation to the year they were published in.

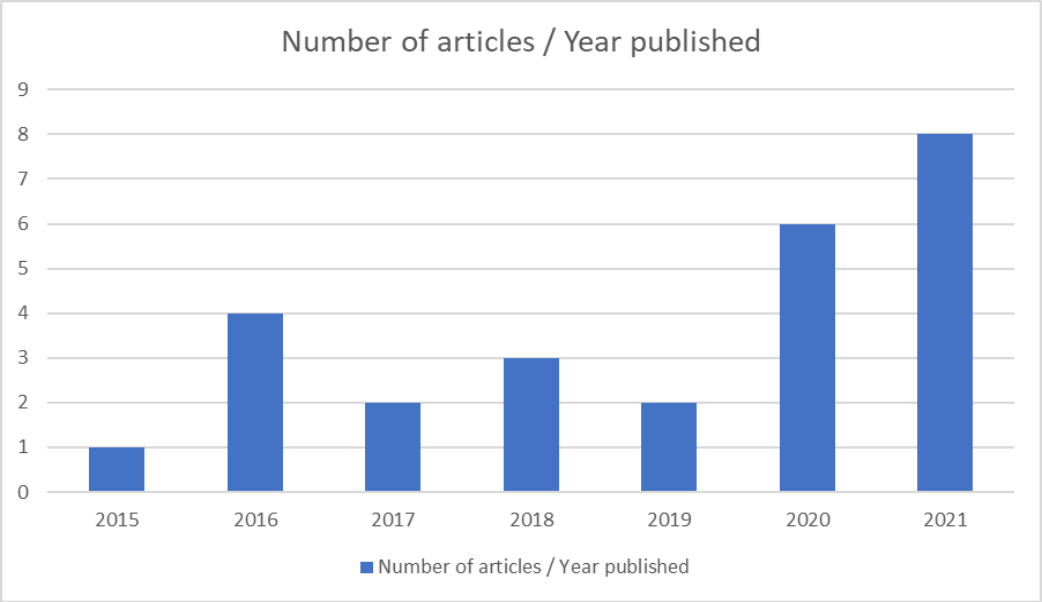

Figure 1: Number of articles / year published

4.2 Findings

In the table below, table 4, the findings are presented with the purpose of summarizing the positive and negative factors that affect ergonomics in a work environment, as well as the causes that make a finding either negative or positive or even both. Here, the full table is not presented in order to limit the extensive, unneeded information. Instead, the full table can be found in the Appendices chapter. The negative and positive findings are highlighted using a square for negative and a dot for positive.

- ☐ *For negative*
- ● *For positive*

Study type	Author/s	Findings	Positive	Negative	The cause that makes the finding negative or positive
Review paper	Amiri & Behnezhad, 2020	☐ Stress at work increases the tension of the human body. This can lead to musculo-skeletal pain.		❌	☐ If a worker is affected with musculo-skeletal pain, it could further lead to injuries and severe pain and thus MSDs.
Article	Bai & Wicaksono, 2020	• With a suitable working environment, the safety and health of workers can be ensured.	✅		• It leads to higher productivity in the production systems.
Case study	Bautista et al., 2016	☐ Higher ergonomic risks affect workers' psychological and physical comfort.		❌	☐ This could lead to several pain in the human body particularly in the back, as well as mental and physical fatigue.
Case studies	Bergman et al., 2021	• With the help of a more sustainable level of cognitive workload in the assembly work, a balance between work requirements and work resources can be achieved.	✅		• A sustainable cognitive workload enables fitters to perceive relevant signals from the assembly situation, recognize, process, interpret them etc.
Case study	Botti et al., 2017	☐ Repetitive manual tasks lead to the same ergonomic risk.		❌	☐ Workers performing the same task are assumed to be exposed to the same ergonomic risk level.

Table 4: Findings based on positive or negative factors.

4.3 Positive Effects

4.3.1 Work environment

When designing workstations, Colim et al., (2021) argues that it is crucial to consider the workers' perspective and keep them in mind. This could be done by involving them in the design process of an assembly line for example, which allows them to participate and feel trusted. According to Bai et al., (2020), the safety and the health of workers can be ensured through a suitable working environment. A suitable workplace is where the employees are satisfied due to various factors such as privacy, opportunities for communication, calming rooms etc, which in turn result in optimization of productivity. Thus, the organization automatically becomes affected positively. It is considered "positive" since a healthy workplace affects the employees' satisfaction to a great extent (Voordt et al., 2021). Moreover, Bai et al., (2020) also mentions that a healthy working environment results in higher productivity which the worker's satisfaction plays a role in achieving.

4.3.2 Well-balanced workload

In assembly work with different types of work requirements, it is important to maintain a sustainable level of cognitive workload (Bergman et al., 2021). When an operator is exposed to difficult tasks such as tasks with robots, it is important to understand the mental workload of the operator in order for it to become balanced. This improves the performance of the workers as well as the organizations' effectiveness (Chacón et al., 2021). Bergman et al., (2021) also mentions that it is expected from a manager to be able to offer work resources, such as necessary training sessions and tools, to be able to guide and support the worker and their learning process. As a result, their workload will become more balanced. The advantages of a sustainable cognitive workload are that it enables fitters to perceive relevant signals from the assembly situation, recognize, process, interpret them etc. In addition, with the help of a sustainable level of cognitive workload in the assembly work, a balance between work requirements and work resources can be achieved (Bergman et al., 2021).

4.3.3 Integration of human factors in production process design

One of the essential factors of ergonomics is to integrate HF in the design process of a production workplace. This includes both the design of workstations and the overall

business goals of the companies. To achieve this, it is required to teach HF specialists all about engineering tools and the language of processes. Here, the specialists' own experiences of the workers' skills and abilities can contribute to the productivity of the organization in general (Village et al., 2015). Furthermore, according to Colim et al., (2021), it is crucial for the worker or the operator to be involved in the design of the workstation, from the beginning. This does not only increase the workers' motivation, but their mental health improves as well, which in turn leads to encouragement among all employees (Colim et al., 2021). Both Rinaldi et al., (2021) and Mossa et al., (2016) mention in their articles that job rotation leads to a reduction of any ergonomic risks. Additionally, with job rotation, the worker can be assigned a suitable task with consideration, for example of the workers physical characteristics etc. (Rinaldi et al., 2021). There are other factors that lead to a healthier and a more productive workplace. For example, according to Jinnett et al., (2017), through implementing a safety investment strategy at organizations the productivity increases, and at the same time the absence decreases. Productivity increases also through job rotation, when an appropriate rotation of workers takes place, through it the ergonomic risks are also reduced and balanced (Mossa et al., 2016).

4.3.4 Automation and collaborative robots

The application of HRC into an assembly line can minimize the risk of harm or injuries of the human operators, thereby improving their physical health at work (Gualtieri et al., 2020). Robots are used with the purpose of supporting workers by carrying heavier and larger objects for example. However, this collaboration has to ensure the workers' safety first (Vysocky & Novak, 2016). According to Vysocky & Novak, (2016), robots and human operators can interact while making sure safety is achieved as well. This could be done in different ways such as, humans and robots could perform work at the same place, but separately. In other words, the robots will stop moving when the worker approaches that specific place of work. On the other hand, Mohammadi Amin et al., (2020) argues that even though safety is ensured by the traditional ways of collaboration, productivity becomes limited to a great extent. Therefore, the use of a mixed approach intelligent system between visual and tactile perception results in more satisfactory results. Lastly, Colim et al., (2020) states that in some assembly line systems' the integration of collaborative robots will maintain the flexibility while at the same time, increase productivity. This will make workers more satisfied since the Cobots will take over on the more challenging tasks. Consequently, safety can be guaranteed without the need to slow down productivity or affect flexibility (Mohammadi Amin et al., 2020).

Positive effects	Number of papers
Work environment	3
Well-balanced workload	2
Integration of human factors in production process design	5
Automation and collaborative robots	4

Table 3 - The various positive factors linked to the number of papers found.

4.4 Negative Effects

4.4.1 Poor implementation of Ergonomics

A highly important element of ergonomics or HF (which is a synonym to ergonomics), is the ability to address them during the phase of designing a work or a process. When this procedure fails to be completed properly, major problems can easily occur (Neumann et al, 2021). There are essential negative effects that take place as a result of the failure to identify ergonomics during workstation design. These effects could be physical, psychological and/or muscular workload (Kolus et al., 2018). Furthermore, physical and muscular workload result in MSDs for example, which can include strain injuries (Neumann et al, 2021). Psychological workload on the other hand, could result in mental fatigue (Kolus et al., 2018). According to Village et al., (2015), the design of HF at work stations and assembly lines needs a large shift in order to achieve improvements in a system. This includes developing the practices of ergonomics and the skills of its practitioners in order to avoid the negative consequences such as fatigue. Also, working on HF design is crucial since not only it minimizes unfavorable results but also improves assembly capabilities and thus increases consistency and improves the performance of employees. In addition, poor implementation of ergonomics usually leads to different problems as a result of the following actions: repetition of efforts, poor body postures, work stress and poor instructions (Neumann et al, 2021). These awkward postures and poor actions result in economic losses for different organizations, since they lead to injuries and thus employees will need medical treatment and sick leave. Moreover, a decrease in quality of production will take place as a result of sick workers and thus costs will increase (Ozdemir et al., 2021). This shows that there are many negative consequences to ergonomics at a workplace when implemented poorly. Thereby, the lack of proper consideration of HF in the design of

assembly lines becomes an essential work environment problem (Neumann et al, 2021).

Another major issue in regards to the implementation of ergonomics at a workplace is the lack of variation in the design of workspaces and layouts according to the physical characteristics of the operators. Several characteristics should be taken into account such as body, strength, height, gender, age and skills. The last two have been considered the two most important characteristics when designing an assembly line system. Therefore, it is important to consider new developing models that help aging workers for example, in order to ensure comfortable working postures and less workload and fatigue (Katiraee et al., 2019).

4.4.2 Job strain

Job strain is a factor that plays a great role in affecting the human body and mind. In other words, the higher the job strain, the greater the risk of illness. One of the most common risks of job strain is the cause of MSDs. This problem could occur, because when a worker is faced with high levels of stress at a job, any muscle tension could be increased and thus result in musculo-skeletal pain (Amiri & Behnezhad, 2020). Here, it is noticeable that when the cognitive aspect of ergonomics is affected i.e. work stress, it will in its turn affect the physical aspect as well which is the human body as a whole. Therefore, it is as important to consider the psychological comfort of workers which includes autonomy, suitable work environment and social relations, as it is to consider the physical comfort. However, workers are also exposed to pain and discomfort at assembly lines due to some challenging tasks, resulting thereby in work-related MSDs (Colim et al., 2020). When an operator is exposed to the risk of physical and social discomfort due to job strain, the risk of experiencing illness increases (Bautista et al., 2016). Moreover, according to Botti et al., (2017), since high-strain jobs result in MSDs, costs for different aspects like treatment will become higher for organizations.

4.4.3 Repetitive manual tasks and unbalanced effort

An assembly line usually consists of repetitive tasks that a worker has to complete which involves bending, gripping, holding, reaching, twisting etc. (Digiesi et al., 2018). Also, some tasks can include a crouching position due to the need to work under an object which results in pain in different parts of the human body such as the neck, back, feet and ankles (Gonen et al., 2016). Even though human beings have the flexibility to perform these repetitive tasks, it is still considered dangerous in terms of their health and it could lead to a plenty of issues in the long term (Digiesi et al., 2018). The main concern in terms of a worker’s health is the great risk of harm that leads to MSDs.

Further concerning issues could take place which include the prevention of desired production and quality levels. This is due to the absence of workers and higher costs of rehabilitation and treatment which hinders the development of production efficiency. On the other hand, the cost of substituting injured workers with new ones increases especially since training new employees requires time and effort (Botti et al., 2017).

Another aspect that should be taken into account is the unbalanced physical effort put into the tasks by assembly line workers. For example, when one assembly line worker does more physical work than another worker, the first worker will be exposed to different physiological disorders due to the excessive effort. Therefore, adding or excluding an extra workstation or worker for example, might be needed to ensure the balanced effort among workers (Zamzam et al., 2021).

4.4.4 Lack of needed skills

According to Kamarulzaman MK et al., (2020), operators struggle to be satisfied in a work environment due to their limited skills. This on the one hand could be a result of the worker's limited abilities to learn, on the other hand however, it could be a result of poor training. In order for workers to be trained well to meet the expectations at a workplace, the HF trainers need to be taught as well. That is, it is crucial for supervisors, production engineers and practitioners to be trained well in order to be able to provide the necessary knowledge and skills to operators (Village et al., 2015). Occasionally, a worker's learning ability gets affected by the leader’s attitude. In other words, when a line leader’s behavior at an assembly line results in a stressful work environment, workers’ ability to understand more complex tasks becomes limited. As a result of all these situations, an untrained worker affects all employees as a whole. This is because when a worker is exhausted mentally and physically due to limited skills, the exhaustion contributes to workload among other workers as well (Kamarulzaman MK et al., 2020). Therefore, it is highly important to focus on training practitioners, operators, as well as to conduct more research on the proper methods and tools in order to guide training. Thus, workers become healthier in different aspects and productivity becomes optimized at workplaces (Village et al., 2015).

4.4.5 Automation (Cobots)

Even though there are many ergonomic benefits for integrating robotics and automation in assembly lines, this integration still raises different concerns (Kadir et al., 2019). The first concern is safety which could evoke when humans and robots interact in assembly stations (Vysocky & Novak, 2016). Traditional robots are considered to be risky to some extent, especially when compared to cobots (Kadir et al., 2019). Cobots stop

immediately when the domain of the operation is somehow disturbed in order to avoid any possible injuries and therefore, cobots are one of the safest automation methods. However, even these new methods could cause damage when a specific piece of equipment is hanged or attached to a cobot (Vysocky & Novak, 2016). According to Neumann et al, (2021), some automation studies show that working downstream from a robot increases the amount of the operator's repetitive movements, increasing thereby the risk of injuries. In other words, even though the integration of robots minimizes the tasks completed by humans, it can still increase their small movements which affect workers negatively.

Secondly, flexibility is considered another concern when it comes to automation technologies. This is because there are numerous tasks that require human integration since robots are still not able to complete the more complex tasks whereas human operators are flexible (Tiacci & Mimmi, 2018). Flexibility is a major requirement in regards to physical ergonomics where operators have to carry through repetitive actions that require strength (Kadir et al., 2019). Therefore, the lack of flexibility becomes a negative factor since it results in exhaustion and possible MSDs that affect the human body negatively (Tiacci & Mimmi, 2018).

Negative effects	**Number of papers**
Poor implementation of ergonomics	5
Job strain	4
Repetitive manual tasks and unbalanced effort	4
Lack of needed skills	2
Automation (Cobots)	4

Table 4 - The various negative factors linked to the number of papers found.

5. Analysis and Discussion

In this chapter, the research question and sub question are answered by analyzing and discussing the results of this paper with the help of the theoretical framework. Also, the similarities and differences between the positive and negative factors are discussed and analyzed.

Automation and Cobots

There are various similarities and differences when it comes to the positive and negative effects of ergonomic factors at assembly lines' work environments. Firstly, In terms of the positive and negative factors, automation and cobots take up a great place. The main similarity is that they both can influence the work environment anyway, whether positively or negatively in regards to ergonomics. On the other hand, the difference is the way in which they influence it. For example, when it comes to the positive effect, different authors state that robots support workers in carrying heavier payloads, thereby, the risk of injuries due to heavy objects decreases (Gualtieri et al., 2020; Mohammadi Amin et al., 2020). Nonetheless, Vysocky & Novak, (2016) argue that human-robot interaction is still considered risky when it comes to safety measures. This is especially concerning when traditional robots are used (Kadir et al., 2019). Even so, Vysocky & Novak, (2016) still believe that it is possible to ensure the safety of human operators to a great extent in ways such as that a robot will stop working when a worker approaches the same place as the robot. Another way to ensure safety is the use of a mixed approach intelligent system (Mohammadi Amin et al., 2020). In spite of this, if a piece of object is hanged to the robot, it could fall, which still makes it dangerous (Vysocky & Novak, 2016). Here, it is noticeable that HRC is beneficial to different organizations in terms of higher productivity in many cases as well as support for workers (Colim et al., 2020). However, according to many authors of the articles reviewed, automation is until nowadays, considered to be risky to some extent and its flexibility limited, which has a direct effect on employees and especially on human operators who work on the same floor as the robots. (Kadir et al., 2019; Vysocky & Novak, 2016; Tiacci & Mimmi, 2018).

The level of Implementation of ergonomics

Another topic that has a great effect on the way sufficient ergonomics is achieved, is the amount and quality of integration of HF at an assembly line. Many authors agree that this includes addressing the HF right from the beginning of a process or a design, training HF specialists, involving workers in the design of an assembly line etc. (Village et al., 2015; Colim et al., 2021; Neumann et al, 2021). The main similarity here is that

these factors play a great role in shaping ergonomics at a workplace, Yet, they are considered to have negative effects when implemented poorly or/and positive effects when considered properly. Firstly, the sufficient training of HF specialists can contribute to the health and productivity of workers. When the specialists are trained properly and are involved in an organization at the early stages, the productivity of workers increases due to the specialists' skills (Village et al., 2015). On the other hand, the same author mentions that a limited amount of training provided for practitioners and leaders would result in workers having limited skills and thus it turns into a negative factor. This is a problem because when an assembly line leader evokes stress at work, some workers' ability to understand different tasks become tougher (Village et al., 2015). Also, In order to improve the motivation and the productivity of workers, they should be involved in the design of new workstations which makes them feel trusted and thus they feel supported mentally (Colim et al., 2021). Here, managers have the largest responsibility of providing the proper tools and training materials for employees (Bergman et al., 2021).

Job Rotation

Another point that is considered important to integrate and would be beneficial for workers is job rotation, since each worker can be assigned to the job that he or she fits in, thereby limiting ergonomic risks (Rinaldi et al., 2021; Mossa et al., 2016). However, the failure to apply HF properly when designing a workstation could result in physical and muscular workload of human operators. The workload can eventually result in MSDs, which thereby leads to increased costs and losses for the organizations. The economic losses increase due to sick leaves and the need for treatments (Neumann et al, 2021; Ozdemir et al., 2021). According to Katiraee et al., (2019), another negative factor that leads to undesired consequences is the lack of considering different characteristics of human beings such as age, height, gender etc. Regardless, this issue can be solved by implementing job rotation for example which is considered a positive factor of ergonomics (Rinaldi et al., 2021).

Repetitive manual tasks

Furthermore, other aspects such as job strain and repetitive manual tasks are negative factors that can have a detrimental impact on the human body while working at assembly lines (Amiri & Behnezhad, 2020). Likewise, when a worker experiences high levels of stress or performs repetitive manual tasks like crouching, the risk of injuries and MSDs increases (Digiesi et al., 2018; Gonen et al., 2016). Regarding the stress levels, Bergman et al., (2021) states that it is important to keep a sufficient level of cognitive workload in order to avoid any harm. This can be achieved through convenient training sessions as well as ensuring that workers are provided with meetings for

communication (Bergman et al., 2021; Bai et al., 2020). In terms of the repetitive manual tasks, authors state that it is of great risk to feel pain in several parts of the body and even experience MSDs. Thus, the effectiveness and productivity are both reduced due to the exhaustion and the injuries of workers (Gonen et al., 2016; Botti et al., 2017). Here the integration of cobots can ease the tasks to some extent since cobots have the ability to take care of difficult tasks (Mohammadi Amin et al., 2020).

What is considered the most effective factor?

The results show that, to begin with, the way ergonomics and HF are implemented in a workplace, plays a great role in making a work environment ergonomically healthy. This is because it is the first step that leads to the factors. Even by looking at table 4 and 5, the number of the articles that discuss the topics of the implementation of HF were more than the number of the other articles. This covers both whether HF are poorly implemented or properly integrated. On the other hand, the number of articles is not necessarily an indicator of the importance and effectiveness of the factor. According to the results, one of the most important factors that have a great impact on assembly line systems nowadays is automation. It is fairly obvious that the collaboration of humans and robots results in developments continuously. This is usually beneficial for organizations because it speeds up the processes, makes the tasks easier for employees and increases effectiveness as a whole. However, automation can still be riskier than other factors since it could involve the collision of human operators and heavy robots, especially since many companies still use traditional robots. Over and above that, the implementation of automation is considered essential since it is related to almost every other factor, such as repetitive manual tasks, job strain, flexibility, integration of human factors etc. In one way or another, it has an impact on ergonomics whether negatively or positively and most definitely has the greatest impact along with the implementation of ergonomics on organizations nowadays.

A better ergonomic work environment

In order to provide a better ergonomic work environment for employees and thus achieve an effective production system, several steps should be taken according to this study. After identifying the most important ergonomic factors such as automation and cobots, job rotation, the implementation of HF and repetitive manual tasks, different steps should be considered in order to guarantee the satisfaction of workers and to maximize productivity. However, some factors can turn negative when implemented improperly, therefore safety should be ensured at all times and steps. To start off, the integration of employees and especially operators in the design of workstations from the beginning, allows them to feel trusted and responsible (Colim et al., 2021). Making the

workers feel trusted results in a healthy working environment which thereby leads to higher productivity according to Bai et al., (2020). The next step is to ensure that workers have the opportunity to rest and communicate freely which can be achieved through communication sessions and relaxing rooms (Bai et al., 2020). This is because workers who have a balanced mental workload can complete their tasks more easily. However, in order to provide all of these steps, HF specialists and managers have to be adequately trained and taught to train other employees. This step is crucial since the experiences and knowledge of managers leads to improved results and more satisfied employees (Village et al., 2015). Afterwards, according to Rinaldi et al., (2021) and Mossa et al., (2016), job rotation can be applied where workers can change tasks in order to avoid repetitive work which contributes to their physical health. Here, each worker can also be assigned a task according to his or her ability and physical characteristics. Lastly, HRC is considered an essential ergonomic factor, however, when safety is assured. This is beneficial for both workers and companies since robots can take over the difficult tasks that require repetitive movements decreasing thereby the risk of injuries and sick leaves (Colim et al., 2020; Vysocky & Novak, 2016; Gualtieri et al., 2020). By following these points, job strain, unbalanced effort and injuries can be avoided to a large extent. As a result, a healthy, ergonomic work environment can be achieved where workers are more efficient and happy, and productivity can become maximized.

6. Conclusion and Recommendations

This chapter contains a brief summary of the problem statement, followed by answers to the research questions. Finally, some recommendations are mentioned for future studies.

6.1 Conclusion

The aim of this thesis is to contribute to a better understanding of the importance of ergonomics and address the most important ergonomic factors that influence an assembly line system's work environment. This was conducted through a literature study. In order to be able to achieve this, a research question and a sub-question were answered.

RQ: *What are the most important ergonomic factors that influence an assembly line system's work environment?*

- *What are the positive and negative effects and what causes them?*

The most important ergonomic factors which have the greatest impact on employees firstly and on the whole organizations' performance secondly, are automation and cobots, job rotation, the implementation of human factors, and repetitive manual tasks. Thus, all these factors lead to an impact on assembly lines systems' work environment in different ways as concluded below.

- Automation and cobots are continuously being more common in manufacturing companies due to the development of technology. This shows that despite the fact that robots are taking over the more difficult tasks, the health of the workers is still considered to be triggered. That is, even though automation and HRC can make the job easier for employees, they still can cause damage and health issues which should be considered.

- Job rotation is another factor that influences assembly lines. Assembly lines are known as a line where the employees work in different sections of the line and usually each worker works in the same part all day. In the long run, this leads to health issues due to the long-lasting repetitive work tasks. This is a very common problem among assembly line workers. To avoid repetitive tasks and reduce any ergonomic risks, job rotation can be implemented, and a rotation schedule can be followed.

- The implementation of HF is one of the most important factors that should be considered. It has a big influence on the work environment, and therefore, HF should be taken into account both in the design of workstations and the overall business goals of the companies. This in turn affects the work environment in such a way that the workers' motivation increases and their mental health improves.

- Repetitive manual tasks, as mentioned earlier, are common in assembly-line systems. The repetitive manual tasks result in pain in different parts of the body, which can lead to MSDs.

To conclude, there are various ergonomic factors that play a great role in shaping an assembly line system's work environment. These factors can be considered either positive, negative or both. Automation and HRC can be both positive and negative, depending on how safe a Cobot is for example. The same idea applies to the level of implementation of HF at a workplace. However, other factors such as job strain and repetitive manual tasks are considered negative factors that could result in a harmful environment. Nevertheless, it is possible to improve some of these injurious factors by implementing the positive considered factors. For instance, by integrating ergonomics properly, that is, providing sufficient training and communication opportunities, stressful tasks can become easier. Thereby, a healthier work environment and maximized productivity can be achieved.

6.2 Recommendations

Companies that want to implement ergonomics properly and achieve a sufficient work environment for their employees, should take into account the factors that were mentioned in this study. To further improve this literature study, it can be transformed into a case study at a company or a survey where the mentioned factors can be tested in reality. With a suitable work environment and consideration of ergonomics, companies can achieve much higher productivity and efficiency.

For future studies, exploring the indirect and direct factors that affect ergonomics at an assembly line production system, whether through a literature review or a case study

can turn into useful and sufficient work. In other words, considering what affects ergonomics directly or indirectly. That is, the factors that can have an obvious effect for a short period of time or the factors that could result in an indirect effect which can be observed in the long term only.

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8. Appendices

Study type	**Author/s**	**Findings**	**Positive**	**Negative**	**The cause that makes the finding negative or positive**
Review paper	Amiri & Behnezhad, 2020	☐ Stress at work increases the tension of the human body. This can lead to musculo-skeletal pain.		❌	☐ If a worker is affected with musculo-skeletal pain, it could further lead to injuries and severe pain and thus MSDs.
Article	Bai & Wicaksono, 2020	• With a suitable working environment, the safety and health of workers can be ensured.	✅		• It leads to higher productivity in the production systems.
Case study	Bautista et al., 2016	☐ Higher ergonomic risks affect workers' psychological and physical comfort.		❌	☐ This could lead to severe pain in the human body particularly in the back, as well as mental and physical fatigue.
Case studies	Bergman et al., 2021	• With the help of a more sustainable level of cognitive workload in the assembly work, a	✅		• A sustainable cognitive workload enables fitters to perceive relevant signals from the

		balance between work requirements and work resources can be achieved.			assembly situation, recognize, process, interpret them etc.
Case study	Botti et al., 2017	☐ Repetitive manual tasks lead to the same ergonomic risk.		❌	☐ Workers performing the same task are assumed to be exposed to the same ergonomic risk level.
Case study	Chacón et al., 2021	• Understanding the workers' mental workload is highly important	✅		• It improves the worker's performance.
Case study	Colim et al., 2020	☐ Assembly line workers have a major risk of experiencing work-related MSDs. • The Implementation of automation and especially Cobots will improve the situation.	✅	❌	☐ These workers will feel pain in different parts of their bodies as well as discomfort while working. • Workers will be able to work with more comfort and as a result, productivity will be increased.
Case study	Colim et al., 2021	• The involvement of operators and workers in the design of workstations from the beginning is crucial.	✅		• It increases the workers' motivation and satisfaction thereby improving their mental health at the workplace.
Article	Digiesi et al., 2018	☐ Repetitive and monotonous tasks take place because of manual activities.		❌	☐ The repetitive tasks could become responsible for MSDs.
Case study	Gonen et al., 2016	☐ Particular working positions like crouching are physically inappropriate.		❌	☐ The poor working positions result in pain in back, feet, ankles, neck etc.
Case study	Gualtieri et al., 2020	• Associating a collaborative robot with a human operator at assembly lines	✅		• The main goal is to support the workers while ensuring their safety.

Survey	Jinnett et al., 2017	• Wellness and safety investment strategy is helpful when implemented at organizations.	✅		• This improves the health of the workers, as well as increase their productivity and decrease the absence.
Systematic literature review	Kadir et al., 2019	☐ Robots are still not fully flexible, i.e. they are unable to complete all complex tasks.		❌	☐ The lack of flexibility in robots means that humans still have to complete repetitive work tasks which result in pain/injuries.
Survey article	Kamarulzaman MK et al., 2020	☐ Lacking needed work skills at workstations have negative consequences.		❌	☐ Lacking skills could be a result of a shortage in training which leads to increased stress levels among workers.
Literature review	Katiraee et al., 2019	☐ Lack of variation in the design of workspaces and layouts according to the physical characteristics of the workers, in terms of body, strength, height, and gender.		❌	☐ Fatigue and health disorders.
Systematic review	Kolus et al., 2018	☐ Quality risk factors such as task difficulty results in physical, cognitive and psychological workload.		❌	☐ Workload leads to physical and mental fatigue for workers affecting their health negatively.
Case study	Mohammadi Amin et al., 2020.	• Introducing collaborative robots is beneficial for companies. A mixed approach of visual and tactile perception is used.	✅		• The tasks are completed collaboratively with safety considerations, however, simultaneously productivity is increased.

Case study	Mossa et al., 2016	• Ergonomic job rotation maximizes the speed of production while assigning the most suitable fitter to workstations.	✅		• Through an appropriate rotation of workers, it results in the possibility of increasing productivity as well as reducing and balancing ergonomic risks.
System framework	Neumann et al, 2021	☐ Failure to consider ergonomics properly when designing a workplace can occur.		❌	☐ If ergonomics are neglected, employees are affected negatively, both physically and mentally since ergonomics at work are essential for health.
Case study	Ozdemir et al., 2021	☐ A poor ergonomic design of an assembly line causes WMSDs.		❌	☐ This might further result in economic losses due to job absence, medical treatments, manual processes, worker rehabilitation, and a reduction in quality.
Article	Rinaldi et al., 2021	• Through job rotation can the worker be assigned a specific task with consideration to the workers physical characteristics etc.	✅		• Job rotation leads to reduction of any ergonomic risks and solves at the same time dangerous situations.
Case study	Tiacci & Mimmi, 2018	☐ Due to limited flexibility of automation, humans are required to perform repetitive tasks with high frequency.		❌	☐ It results in musculo-skeletal disorders.
Case study	Village et al., 2015	☐ Lack of design for human factors. • Human factors should be aligned with the company when it comes to its production design process and business goals.	✅	❌	☐ Leads to increased fatigue and decreased human performance and consistency • It improves workers' well-being, maximizes their performance and ensures their health.

Literature review	Voordt & Jensen, 2021	• Healthy workplaces have a major effect on employees' satisfaction	✅		• When employees are satisfied, productivity becomes optimized and the whole organization becomes affected positively.
Article	Vysocky & Novak, 2016	☐ The collaboration of humans and robots in the industry raises concerns continuously. • Robots are able to help human workers to carry heavier payloads while ensuring safety.	✅	❌	☐ Safety can be affected and workers could be harmed/injured at workstations, especially since not all companies have cobots. • This decreases the risk of injuries since robots are able to carry on the more difficult tasks.
Article	Zamzam et al., 2021	☐ Unbalanced physical effort between workers occurs at some assembly lines such as the two sided ones.		❌	☐ Unbalanced effort leads to more physical damages and possible MSDs