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Research Article

The ergonomic posture assessment by comparing REBA with RULA & OWAS: A case study in a gas springs factory

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ABSTRACT

Occupational health and safety are the most valuable assets for any firm. The hazards that may occur in the workplace should be analysed and studied to minimize the possibility of their incidence. WMSDs (Work-related Musculo Skeletal Disorders) injuries are one of the most common accidents that happen in the workplace in some countries exceeding 40% of the total types of accidents. Thus, many techniques like REBA were innovated to analyse the risks leading to these kinds of injuries. This article studies and analyses 15 postures ergonomically in detail to cover all the working stations in a Gas Springs factory in Türkiye. This high number of postures with real-life cases from a developing country such as Türkiye can be considered an essential contribution to this field. Classical REBA and the REBA calculator are used in the application as tools and methods. Additionally, a comparison between REBA results with RULA and OWAS results for each posture is provided. The application showed that 53.33% of the postures' results were medium-level risks. This percentage displays that the workers aren't at a very dangerous risk level, but executives still should take action to reduce the risk level. This study aims to understand REBA and its importance. The article also shows how to apply Classical REBA step by step and how to use the REBA calculator. Finally, the outputs of this article should be beneficial practically and theoretically. It would be practical for the factory to develop the working stations according to the suggestion and theoretically for researchers to build new studies on it.

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INTRODUCTION

Nowadays Ergonomics has become an essential matter for all sectors, especially the industrial sector. It plays a significant role in the workers' health and safety. WMSDs (Work-Related Musculoskeletal Disorders) are some painful disorders that Ergonomic assessments are interested in evaluating. The assessments focus on evaluating the hazards that may be inflicted on muscles, nerves, and/or joints. These types of evaluations examine the physical load by analysing body movements in one or multiple postures, as well as the strenuous activities that escalate over

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time. Therefore, the ergonomic analyses and evaluations help to prevent musculoskeletal disorders or physiological disorders. It is very significant to start applying the analyses regarding the high number of this type of accidents happening in the industrial sector especially. A study from China stated that the percentage of WMSD accidents in China was about 40.2% in 2018 [1]. This percentage proves that the WMSD accident rate is very high. Also, this study was made in China one of the developed and most important industrial countries all over the world so it is expected that this percentage could be higher in the developing countries. There are many techniques to analyse the risks that could lead to musculoskeletal disorders in workplaces such as RULA, REBA, NIOSH, PATH, OWAS, and QEC. This study is focusing on applying REBA (Rapid Entire Body Assessment) in a Gas Springs Factory in Türkiye. The REBA technique was applied to most of the daily postures of the workers working in the factory. It is very important for all workplaces to start applying techniques like REBA to keep their workers in a safer environment. Al-Madani and Dababneh stated that the importance of REBA lies in the ease and speed of its application which is able to evaluate many postures by dividing the body into sections, coding them, and scoring them in detail [2]. The article didn't evaluate the working postures by REBA only; but also, solutions are suggested to decrease the risks in each posture if needed because REBA should be a non-stoppable cycle until sure that all the workers are working in positions with zero harm for their bodies. The implementation of REBA is done both manually and automatically through a new application that is developed to make the evaluation much easier than it is. Moreover, a comparison is provided between the results of REBA, RULA, and OWAS to understand the differences between these techniques. The literature review goes deeper to explain these techniques and the differences between them and goes through some previous studies in different sectors that applied REBA. But briefly, REBA was chosen because it covers the whole body not like RULA covers only the upper limb, and it is very detailed not as simple as OWAS. That's why using REBA as the main technique was important for this study. Following that, the implementation of REBA was explained step by step in detail to make the application section which was included real postures from a Gas Springs Factory well understandable. The results of this article should show the significance of REBA and similar techniques to evaluate WMSDs and to try to create a safer working environment. Also, the output of this article is an adding value because it examines 15 postures which is a high number, and in a specific industry there are not many studies about it, so it makes a good contribution either for the workers in the same or similar sector, or for researchers regarding to the very detailed information it provides.

The risks that face the workers in the workplaces, especially in factories, increased the need for research and studies to improve the ways and methodologies to prevent the workers from the hazards they may confront. REBA was one of the techniques that many researchers were interested in. That's why there are many studies belt on the REBA technique. The efficiency of REBA was obvious and that was an important factor to attract researchers to work on and improve this technique.

Although REBA is used these days in the industrial sector, it belongs originally to the medical sector. REBA was presented by Hignett and McAtamney in the United Kingdom in 2000 to evaluate the working positions in health care and other industries [2]. After that, REBA started to be applied in many other sectors until it became the main course in some medical and industrial colleges. As shown in Figure 1 [3], although REBA was used mostly in the Engineering and Medical departments in the last ten years, it was used in more than another eight areas. It

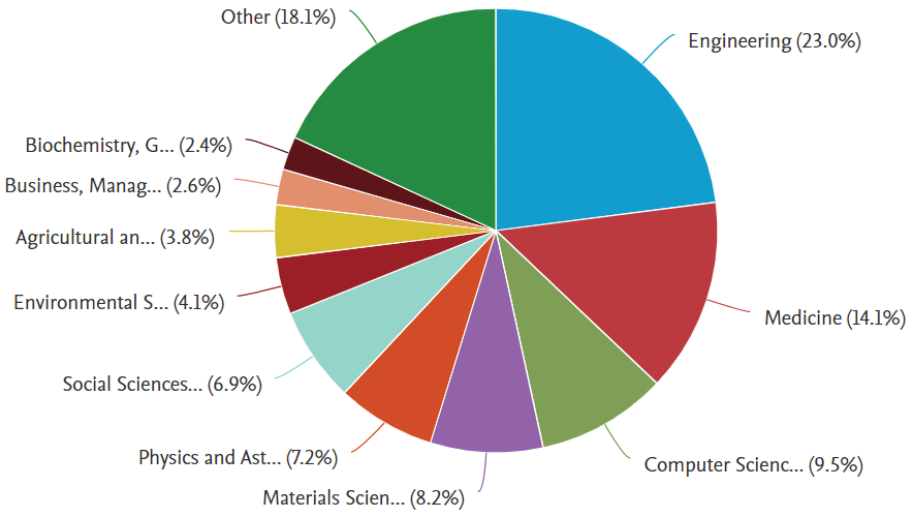

Figure 1. The subject areas of the studies used REBA in the last 10 years.

was easy to be applied which made it spread very widely. According to Joshi and Deshpande, REBA is the most popular technique in that field regarding its ease and speed not only in applying it; but also, speed of getting the results [4]. Additionally, REBA handles a very significant issue which is dealing with WMSDs as mentioned in the introduction. When the musculoskeletal system is exposed to heavy load, it harms the trunk, shoulders, neck, and limps; also, these injuries may lead to paralysis [5]. Thus, REBA is a perfect technique analysing the working positions of the workers before the kind of injuries happen owing to the fact that it focuses on the same body sections to be assessed. REBA divides the body into 2 groups and each one includes sections. Group A includes the trunk, neck, and legs; on the other hand, arms and wrists are included in section B. These are the same sections most likely to get hurt in the musculoskeletal system. According to the position of each section, the score is collected, and the final score leads to the level of risk of the examined posture. REBA has 5 levels of risks from negligible level risk to the level of very high risk. Thus, the evaluators are able to know if there is an action that has to be taken immediately or not.

A lot of industries were in need of REBA to develop the working positions of their workers. REBA was used in different industries in the Industrial sector. In a study made in 2021 that tested 180 postures in the textile industry by REBA, more than 30% of the postures were evaluated as high-risk [6]. This number is enormously big and leads to serious issues. The sections that were highly effected were the wrist with a significant percentage of 84.41%, the lower arm with a significant percentage of 79.31%, and the neck with a significant percentage of 67.24% [6]. So, relying on this study the managers are aware of the dangerous postures and can make some modifications to decrease the risks. Similarly, another study was conducted on 12 workers in an aircraft production area. The study shows that after applying REBA, the most body sections that could be hurt in the aircraft industry are the trunk, neck, and arms especially for the coupling area [7]. After these results, it was suggested that more studies should be done in the future to reduce the risks in the workplace. In another study placed on trucks manufacturer, most of the workplace accidents hit the musculoskeletal system and 43% of them harm the trunk section REBA approved the high-risk on the trunk [8]. However, the company was able to decrease the risk rate after more REBA studies. In the same automotive sector, a study was conducted on nine workers practicing the usual three tasks. The result of REBA was that all three tasks were classified as high-risk postures and the company is working on decreasing the risk level [9]. All in all, applying REBA was very efficient in different industries in the production and manufacturing sectors.

As was mentioned, REBA was invented for the medical sector at the beginning, but it started to be used in many other sectors. In the medical sector, a very recent study had been made for a doctor who was working for a long time in the same posture during the pandemic of COVID-19. The score he got was 8 which means the high-risk that was affecting the trunk the most and the neck after it [10]. It was very important in the pandemic period to examine these positions because of the stressful atmosphere that the doctors were living in. REBA was also used in the Agricultural sector. A study that evaluated working positions for forest nursery workers was conducted on six different agriculture processes. As a result, 53% of postures in only one process were classified as high-risk postures [11]. This percentage means that more than half of the postures are very risky which increases the possibility of musculoskeletal disorders so the managers or the owners should interfere immediately to reduce this percentage. REBA also was used in restaurants with 30 chefs. Even if it doesn't seem that it is a dangerous job however the results showed the opposite. According to this study and after applying REBA, 19.03% of the chefs were at high-risk

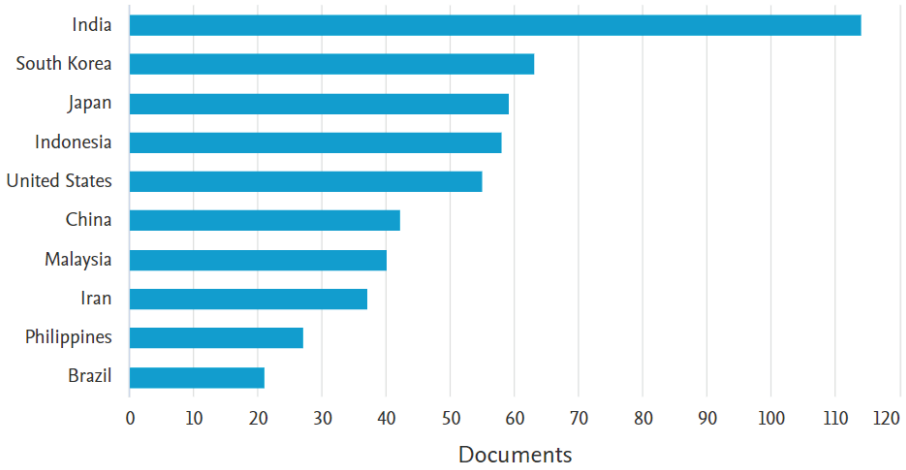

Figure 2. Top 10 countries used REBA in the last 10 years in their studies.

for the neck section then wrist and upper arm [12]. REBA even was used with street vendors and their REBA results were shocking. The study stated that REBA showed that 71% of street vendors are at high-risks, especially for the upper and lower arms [13]. In short, REBA proved its efficiency and capability to evaluate the body postures in many different sectors which gives it credibility over other techniques.

Although REBA was invented in Europe, it became popular everywhere from the East to the West. Not only in developed countries, but in developing countries as well. Figure 2 [3] displays that the top 10 countries that used REBA in their studies last ten years were not European countries. This section contains some studies that prove the popularity of this technique which led it to reach even developing countries. In 2018, a great REBA study had been made in Brazil, which covered many dairy farms in Brazil after a survey showed that a lot of milking workers are suffering from musculoskeletal disorders. As a result of the REBA evaluation, 7 postures were classified as high-risk (scored from 8 to 10) and 13 postures as very high-risk (scored over 11), so the study recommended an immediate interference to change some postures, especially the posture of classical squatting for milking because it puts more than 50% of the workers under very high-risk [14]. According to a study in Colombia, 85% of the injuries in the workplace are muscle injuries [15]. Therefore, there was a need for evaluation techniques in order to decrease the number of injuries. El Bosque University conducted a study on 3 different factories metalwork, plastics, and timber company. 13.33% of the postures in the metalworking factory were high-risk postures and 86.67% for middle-risk postures, and the vulnerable sections are neck and trunk; for the plastic sector, 33.34% for high-risk postures, 52.38% for middle-risk postures and 14.24 for low-risk postures, and the vulnerable are wrists and arms; while in the timber company, 43% of the postures were high-risk ones and 57% for middle-risk postures, and the entire muscular structure was threatened with injury [15]. This REBA application gave detailed information about the risky postures that the managers should interfere with to change immediately. According to a study in Iran, 13.1% of the whole budget of the government is the cost of the MSDs so they tend to use techniques such as REBA, RULA, and even try new techniques such as NERBA [16]. There was a study in India also that used REBA on women who work in tea gardens. The main complaint was elbow pain and after applying REBA it was proved that there are high risks on the upper arms after analysing their working postures [17]. So, REBA can be used either before having injuries or after MSDs in both situations it would be effective to find out the problem or to prove it.

Asea Pacific is one of the most regions that use REBA in many studies. The countries there appreciate the efficiency of REBA, so it became obvious to see many academic articles from their universities in English or even in their local languages. Many studies proved the importance of this kind of technique in this region. A study conducted in Indonesia evaluated many postures in some SMEs (small and medium enterprises) by using REBA and the result was that 10.7% of these positions were categorized as very high-risk postures while 60.7% as high-risk postures which is an enormously big percentage that should be decreased immediately [18]. In a survey that included 12 cities and 482 workers in Indonesia, it was found that around 40.5% of their illnesses are caused because of MSDs [19]. Another study in Indonesia too but in the agriculture, sector tried to apply many techniques to figure out the reasons for the increase in the MSDs for the harvesters. It was stated that after using many techniques most of them described the postures as safe low-risk ones, only REBA evaluation showed that at least 4 postures out of 24 are classified as high-risk postures and need to be modified urgently [20]. Indonesia is not the only Asia Pacific country that is interested in REBA, Malaysia conducted some REBA studies too. The Malaysian Occupational Safety dept stated that between 2005 and 2014 the MSDs cases increased from 10 to 675 [21]. That was the alarm to start using REBA and similar techniques in Malaysia. REBA was conducted in many studies in different sectors in Malaysia such as food, clothing, engine oil, and manufacturing; as a result of these studies, only the postures in the engine oil company were described as a moderated level of risks and all the other sectors showed at least 40% of high-risk postures in each company [21]. These were some studies that show the influence of REBA techniques all over the world. The combination between simplicity, speed, and accuracy made REBA the most popular technique to evaluate WMSDs cases even in developing countries.

Some comparisons were provided in this article between some popular assessments. RULA (Rapid Upper Limb Assessment) is similar to REBA while OWAS (Ovako Working Posture Analysing System) is more straightforward in the application section. Therefore, it is significant to mention some previous studies about RULA and OWAS and their relationship with REBA. RULA has many common points with REBA, they are very similar in concept and application. RULA was invented by McAtamney and Corlett in 1993, and it evaluates the body into 2 groups, A which contain wrists, arms, and forearms, and B which contains the torso, neck, and legs to check the possibility of getting MSDs injuries for workers [22]. REBA also focuses on most of the sections that RULA works on. Also, McAtamney was one of the scientists who invented REBA as well. They have very similar scoring steps too, but RULA has only four risk levels while REBA has five levels as mentioned before. The similarity between REBA and OWAS lies in their both interest in the entire body. OWAS was created by a steel manufacturer called OVAKO company from Finland, and it divides the body into three parts which are 4 situations for the back, 3 situations for

arms, and 7 situations for legs plus a score for weight; so, by collecting the number of each position, we get a code from 4 digits that lead to 4 levels action plan [23]. RULA and OWAS have the same number of risk levels and REBA has more than them by 5 levels. A study was made in South Korea to compare these three popular techniques. The examiners chose 209 stressful working postures, and the result was that 72.2% of OWAS's results and 78.9% of REBA's results were classified as low-risk level; however, 63.6% of RULA's results were classified as high-risk level postures [24]. These studies show that each technique has its own characteristics and sometimes it is needed to apply more than one technique in order to decide which one is more suitable for the study. Sometimes the results might be correspondent so they prove the problems or not so a decision should be taken according to the more realistic technique in the examined case. For instance, a study was made in a school in Indonesia that used REBA and RULA to evaluate the seating positions for the students. The final score of REBA was 8 and the final score of RULA was 7, which are both high-risk levels, so the study suggested a new chair design that decreased the risk level [25]. On the other hand, a study used REBA and OWAS to evaluate the risks in the harvest working in Türkiye. The results of OWAS and REBA were different and the risk level of OWAS was lower than REBA; OWAS was easier, but REBA was more detailed, and its details corresponded more with the postures [26]. In the previous study relying more on REBA was suggested because it was more suitable than OWAS for the examined positions. In brief, using more than one technique and making comparisons in every single study enriches the study and increase its value and creditability.

Even though applying more than one technique is very valuable some techniques might fit the application and may not. So, making the choice of which technique is more suitable can differentiate from one sector to another and from industry to another. Sometimes the same sector may need to be evaluated by different techniques according to the tasks or the postures. For instance, there are two studies in the agriculture sector one in Korea and the other one in Canada. The study conducted in Korea was about manual harvesting tasks and after using REBA, RULA, and OWAS, the result of the hit rate was 30.1% for REBA, 33.3% for RULA, and 34.4% for OWAS [27]. The results of this study were very close, and it showed that using any of these techniques wouldn't make a huge difference. However, the study that had been applied in Canada was applied to the operations using agricultural machinery. The study suggested that RULA gave the most satisfactory results and after that REBA came which gave important results too but the evaluation of OWAS proved its weakness in evaluating postures using agricultural machinery [28]. In the second study, OWAS gave the lowest score however it had the highest percentage in manual farming activities, so it is highly recommended to run many evaluations with different techniques to get more accurate results. In Italy, REBA and RULA techniques were applied for the manual wood-chipping process. The results of REBA and RULA were very similar, and they both showed results between medium and high risks, but REBA was able to highlight the risk on the lower limb better than RULA [29]. That's why it was recommended in the study to use REBA to have a better overview. A study made at railway stations used REBA and RULA too on the vendors there. It stated that REBA and RULA gave similar results because they both evaluate the neck, upper arms, and back, which are the risky body sections for the working postures of the vendors [30]. In this situation, we can claim that choosing a technique should be based on the parts of the bodies that exposure to risks. A furniture manufacturer applied REBA and OWAS to study 18 postures to check and redesign the risky ones. REBA's result showed 3 postures with high-risk levels and OWAS also showed 3 postures but only one posture was mutual between REBA and OWAS, and after a questionnaire, the mutual posture was proved to be the one that the company should redesign immediately [31]. As mentioned before, using more than one technique enhances the study and leads to the most accurate possible result.

The need to apply ergonomic assessments in Türkiye increased very much due to the high number of accidents happening in the production area. More than 50% of workplace accidents in Türkiye happen in the manufacturing environments and there aren't enough studies that work on these kinds of accidents [32]. This shows the significance of having more of these studies, especially in Turkish factories. A foundry factory in Türkiye conducted REBA on a critical and common position in the factory. The result of REBA was 10 which means a high risk that needs an immediate and urgent change; so, the working stage had been redesigned taking into consideration the REBA analysis to decrease the risk and the result was scoring 6 after the redesigning as a medium risk [33]. A Turkish textile factory tested 15 postures using REBA for sewing and packaging processes that are generally conducted by women. The REBA results were between 4 and 8 and according to these results, they rearranged the tasks of the workers in a way that the workers change their working positions during the shift so each worker wouldn't work on a posture with high risk the whole day [34]. Another study in Türkiye also applied RULA to decrease the risk on the upper limb of the employees' body. The score had been reduced, the arms and wrist from 12 to 4, and the overall score of the neck, trunk, and leg from 10 to 4 [35]. These touchable results display the efficiency of using ergonomic assessments in Türkiye. For different purposes, a vehicle seat manufacturer in Türkiye applied REBA to test the final product itself. REBA was conducted to test a new design of seats to check their risk level, and the REBA score was 3 which means a low-risk level [36]. Ensuring that the product doesn't put the customers at a high level of risk is a very significant approach that all

factories should take care of. These cases from Türkiye reflect the necessity of ergonomic assessments owing to the gains the appliers have gotten by preserving the health of either workers or customers. Business-wise, applying these assessments is a huge advantage for each country to guarantee safety with economic developments.

It is important to conduct many techniques to analyse postures. Using different instruments such as REBA, RULA, and OWAS in one study gives more accurate results for a risk assessment of WMSDs [37]. Accordingly, a comparison was conducted in this article between the chosen technique (REBA) and another two popular techniques (RULA & OWAS). After all these literature studies, REBA shows that it is one of the most popular techniques to evaluate risks that may cause WMSDs. It proven its efficiency in many fields and sectors all over the world. Also, REBA is more comprehensive and detailed than RULA and OWAS. Therefore, REBA is used to evaluate the working postures for a gas springs factory in the next sections of the article. This enhances the role of the article contribution by proving the efficiency of the used techniques as the literature review displayed and adding a new case study in a new sector to the cases covered by the literature review.

Table 1. Literature review table

No	Title	Date	Source topic	Usage in the article
1	The prevalence and risk factors of work-related musculoskeletal disorders among electronics manufacturing workers: A cross-sectional analytical study in China	2023	Detecting the reality of the statistics regarding WMSD injuries through questionnaires from 30 factories in China to check the extent of its spread and effects	The percentage of WMSD injuries in China
2	Rapid entire body assessment: A literature review	2016	Giving a review summarizing the application of REBA presenting its applicability, limitations, and validity in different sectors such as industrial, constructional, and medical sectors	REBA's history and importance
3	Analyze search results for REBA	2023	Statistical graphs by Scopus which display information about the studies that had been made using REBA	The fields and countries applied REBA in 10 years
4	Investigative study and sensitivity analysis of rapid entire body assessment (REBA)	2020	A detailed study to evaluate the REBA as an assessment tool and discuss its sensitive and insensitive zones while assessing the postures	The popularity of REBA
5	Ergonomic evaluation of working position using the reba method – case study	2019	A case study using REBA to evaluate the risk level for a waterjet operator working on cutting different complex materials such as plastic, rubber, and metal	Vulnerable sections of the musculoskeletal system
6	Investigation of ergonomic working conditions of sewing and cutting machine operators of clothing industry	2021	Assessing 180 different working postures in the textile sector in SMEs using REBA	Using REBA in textile industry
7	Ergonomics study among operators in water-jet production area in the aircraft industry	2020	Creating an assessment model combining ERA, REBA, and MAC to evaluate the risk level of 12 workers working in the water jet production area	Using REBA in aircraft industry
8	New challenges regarding the intervention of musculoskeletal risk in truck service garages	2022	Minimizing the risk level of the working postures in the Automotive sector in Spain by applying REBA on bus and truck garages	Using REBA in truck industry
9	REBA evaluation on garage worker: A case study	2018	A risk assessment using REBA was applied to nine workers in a vehicle maintenance garage to check the risk level of their working postures	Using REBA in automotive industry
10	Work related musculoskeletal risk assessment Using REBA assessment tool in a medical doctor during COVID-19 pandemic - A case study	2022	Assessing the working postures of the doctors in the COVID-19 period by using NRS for overall pain analyses and REBA for detecting the risk level	Conducting REBA in the medical sector

Table 1. Literature review table (*continued*)

No	Title	Date	Source topic	Usage in the article
11	Comparison of ergonomic risk analysis methods for working postures of forest nursery workers	2019	Using OWAS, REBA, and RULA to detect the risk level of forest nursery working postures and checking which one of the 3 tools would give the more sensitive results	Conducting REBA in the agricultural sector
12	Assessment of posture related musculoskeletal risk levels in restaurant chefs using rapid entire body assessment (REBA)	2021	Using the REBA sheet to assess 30 postures for 30 different chefs to evaluate the risk levels that may cause WMSDs	Conducting REBA in restaurants
13	Ergonomic evaluation of street vendors as determined by rapid entire body assessment method	2021	Analysing the risk level of the working postures of the street vendors by using REBA on 60 workers and detecting the most affected parts of the body	Conducting REBA with street vendors
14	Health in the rural environment: A postural evaluation of milking workers in Brazil	2018	Detecting the parts of the body and muscles that get hurt during the milking processes in some Brazilian farms	Presenting a study from Brazil
15	Evaluation of disergonomic risks in small and medium-size enterprises (SMES) in Bogotá	2020	Evaluating the risks in 3 different factories in Bogotá working in metal, plastic, and wood sectors by applying REBA on 76 workers in 48 different postures	Presenting a study from Colombia
16	Ergonomic assessment of posture risk factors among iranian workers: An alternative to conventional methods	2018	Testing a new ergonomic assessment tool called NERPA by comparing it with REBA and RULA by conducting them on 455 employees of different companies in Iran	Presenting a study from Iran
17	Prevalence of musculoskeletal disorders and their association with ergonomic physical risk factors among women working in tea gardens of Darjeeling district of West Bengal, India	2021	Checking the extent of the spread of WMSDs among the women who work in tea plucking in India by applying REBA on 210 worker	Presenting a study from India
18	Ergonomic assessment in metal-based small industries in Bogor Regency, Indonesia, 2019	2021	Ergonomically analysing the working postures in the metal sector in the SMEs using REBA as an assessing method and NMQ to collect data	Indonesian experience with REBA
19	Analysis of operator body posture packaging using rapid entire body assessment (REBA) method: A case study of pharmaceutical company in Bogor, Indonesia	2020	Using REBA to decrease the percentage of workers' absences that usually happens because of WMSD injuries in a pharmaceutical warehouse in Indonesia	Indonesian experience with REBA
20	Assessment of work postures on non-mechanical rice harvesting (case studies in Bantul and Sleman Districts, Diy Province)	2020	Detecting the high-risk postures in 5 different operations of the rice harvesting process by conducting OWAS, QEC, REBA, and PERA on 9 healthy workers	Indonesian experience with REBA
21	Ergonomic posture assessment of butchers: A small enterprise study in malaysia food industry	2019	Identifying the risk postures of the butchers working in SMEs by using REBA and RULA in Malaysia	Presenting a study from Malaysia
22	Musculoskeletal risks: RULA bibliometric review	2020	Presents a literature review studying RULA using 226 academic papers and comparing the results with REBA and OWAS	Introducing RULA
23	Musculoskeletal disorders: OWAS review	2017	Presents a literature review studying OWAS in many fields and in different countries using 166 academic articles and conference papers	Introducing OWAS
24	Comparison of OWAS, RULA and REBA for assessing potential work-related musculoskeletal disorders	2021	The study compares the results of OWAS, RULA, and REBA conducted on 209 daily routine postures in different workplaces	Comparison study between REBA, RULA, and OWAS

Table 1. Literature review table (*continued*)

No	Title	Date	Source topic	Usage in the article
25	Analysis of musculoskeletal complaints disordered with REBA method and RULA method	2021	A study built on REBA and RULA analysis to design an Ergonomic Learning Chair to decrease the Musculoskeletal Disorders in classes	Comparison study between REBA and RULA
26	Comparison of ergonomic risk assessment outputs from OWAS and REBA in forestry timber harvesting	2019	Assessing the harvesting postures in the forests using REBA and OWAS with combating their results	Comparison study between REBA and OWAS
27	Application of AULA risk assessment tool by comparison with other ergonomic risk assessment tools	2020	Generating and testing a new ergonomic assessment specializing in Agricultural activities called AULA and comparing it with RULA, REBA, and OWAS	Comparison study between REBA, RULA, and OWAS
28	Comparison of methods for postural assessment in the operation of agricultural machinery	2018	Assessing tillage operation using agricultural machinery through RULA, REBA, OWAS, and TOR-TOM to indicate the similarities and differences between the techniques	Comparison study between REBA, RULA, and OWAS
29	Risk assessment for musculoskeletal disorders in forestry: A comparison between RULA and REBA in the manual feeding of a wood-chipper	2019	Using REBA and RULA to assess the working postures of feeding the woodchipper machines manually and comparing the results	Comparison study between REBA and RULA
30	Postural analysis through RULA, REBA and QEC of vendors selling edible items at railway stations and in the trains	2019	Evaluating the postures of the hawkers or street vendors ergonomically in the train stations using RULA, REBA, and QEC	Comparison study between REBA and RULA
31	The proposed improvement of work posture as an attempt in lowering the risk of musculoskeletal disorder	2018	Testing 18 postures in the production area of a furniture factory using QEC, REBA, and OWAS	Comparison study between REBA and OWAS
32	The assessment of occupational safety and health in Turkey by applying a decision-making method; MULTIMOORA	2020	Studying the number of accidents in Turkish workplaces according to the recorded data using a multi-objective decision-making tool called MULTIMOORA	The situation of workplace accidents in Türkiye
33	Ergonomic analysis of working postures in a foundry workshop by digital human modelling based REBA method	2020	Improving the productivity level by using DHM to analyse the working postures and supported by the simulation software CATIA V5 in a foundry factory and REBA was used to identify the risk levels	An implementation of REBA in Türkiye
34	Model proposal for physically ergonomic risky personnel scheduling problem: An application in textile industry for female employees	2023	Identifying the high-risk postures in a textile factory by applying REBA on 15 different postures to prevent the workers from working in the high-risk positions permanently	An implementation of REBA in Türkiye
35	Ergonomics assessment and redesign of helicopter transmission assembly fixture using digital human models	2021	Using RULA and BMA to analyse the working posture ergonomically in helicopter transmission assembling workstation in order to design a new assembling line	An implementation of RULA in Türkiye
36	Biomimetic based design and analysis of vehicle seat back support	2022	Applying REBA to test the ergonomic situation of the car seats to develop the best shape and used materials for the backbone	Using REBA for testing products in Türkiye
37	Does motor manual pine oleoresin tapping bring work-related musculoskeletal disorders risk to the tappers? (RoM, REBA, RULA, and OWAS based postural analysis)	2023	Using RoM, REBA, RULA, and OWAS as ergonomic assessment techniques to evaluate the risk levels causing WMSDs during the motor manual tapping process to produce pine oleoresin	The importance of conducting more than 1 technique

MATERIALS AND METHODS

This study has applied the classical REBA technique in the whole study. However, it was important to give a synopsis about another form of REBA which is REBA calculator. REBA was chosen because it deals with the entire body and it is a very detailed method; so, it was expected that it would be more suitable for the working postures in the factory. Moreover, this study made a comparison between the result of REBA, RULA and OWAS for all the postures provided in the study. The whole study was conducted by the production planning engineer of the factory with the main purpose of decreasing the risk level of all work postures in the factory.

Classical REBA

REBA is characterized by its simplicity and speed in application. It can be done by supervisors or researchers easily anytime. That's why it is very effective when the evaluator is keeping re-evaluating after each result and modification on the postures so REBA should be stay a non-stoppable cycle until guarantee the safeness of each posture in the workplace.

The full REBA worksheet is as shown in Figure 3 [38]. There are two groups and three tables. Group A assesses neck, trunk, and leg positions. Group B evaluates upper & lower arms and wrists. The score of group A should be assign on table A, and similarly the score of group B should be assign on table B. Then, the output of table A plus force score and table B plus the coupling score should be assign on table C. The output of Table C plus the activity score gives the final REBA score and accordingly, the action should be taken.

REBA scoring sheet is also a useful sheet that can be used during the evaluation to write down the score of each position as Figure 4 shows [39].

Group A:

Firstly, the score of the neck position should be decided according to its angle as shown in Figure 5. If the angle is 20 degrees or less, the score should be 1. If more than 20 or in backward move the score should be 3. In the condition of twisting or bending, we add 1. So, the score of the neck should be from 1 to 3 points.

Secondly, if the trunk is in straight position the score should be 1 point. With less than or equal 20 degrees bowing or in backward position the score should be 2. From 20

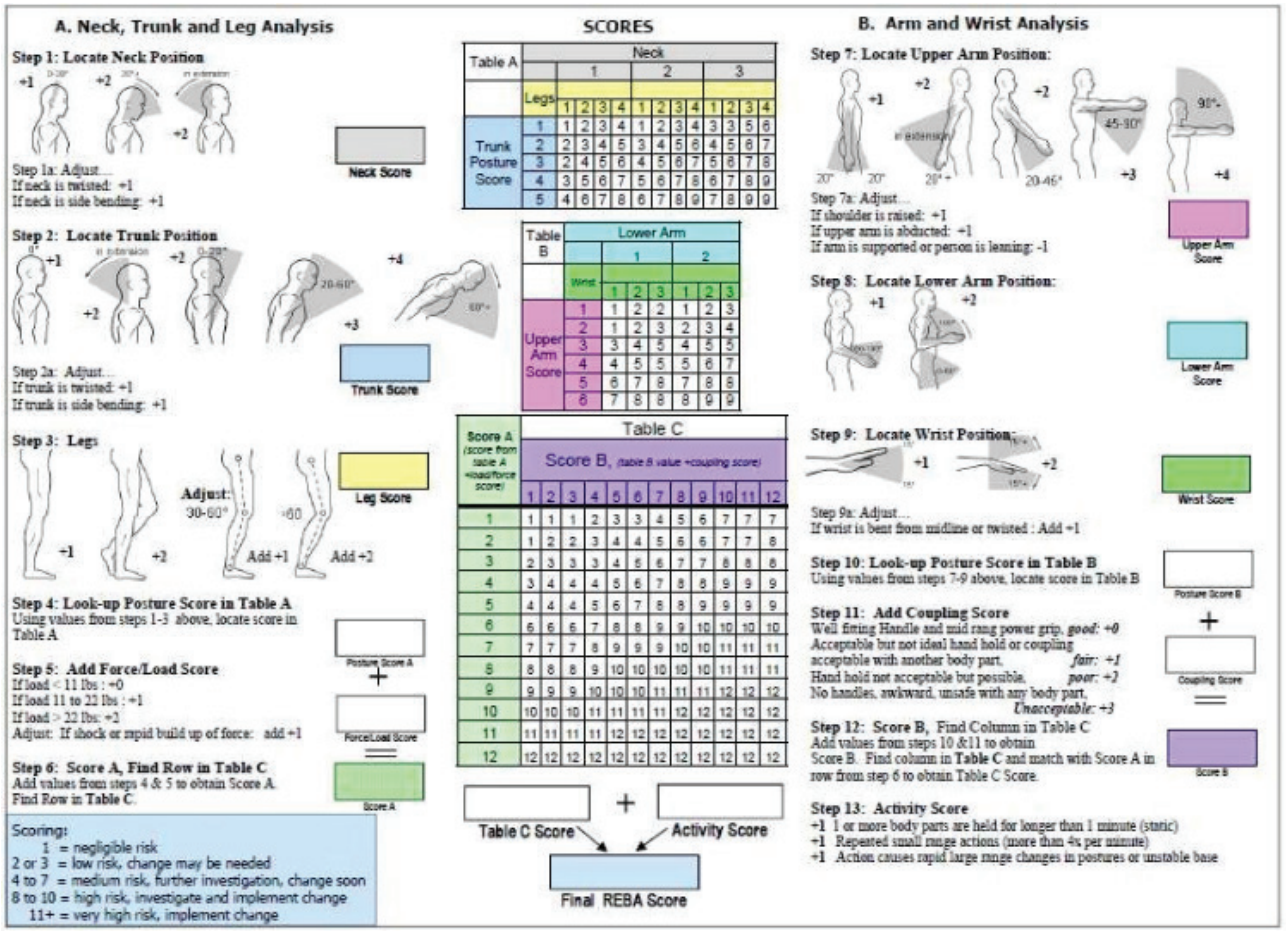

Figure 3. REBA employee assessment worksheet.

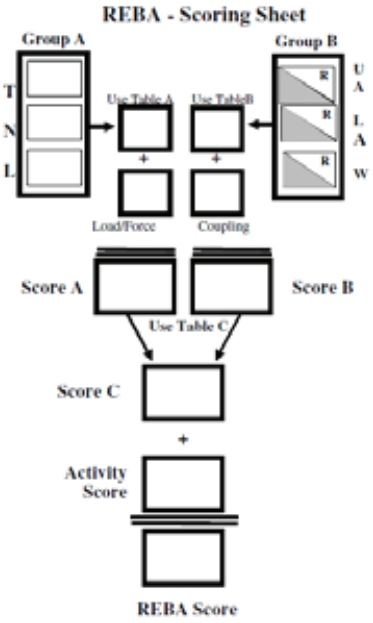

Figure 4. REBA scoring sheet.

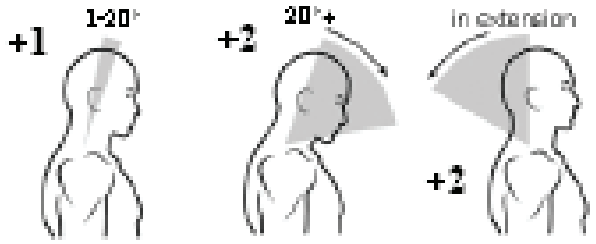

Figure 5. Neck position.

to 60 degrees the score should be 3 and 4 for more than 60 degrees as shown in Figure 6. As the neck there is an extra 1 point for twisting or bending to be add. The final score of the trunk should be from 1 to 5 points.

Thirdly, if both legs in the same position, their score should be 1 and if not, the score should be 2. After that, if there is adjusting between 30 and 60 degrees, 1 point should be added and if it is more than 60 degrees, 2 points should

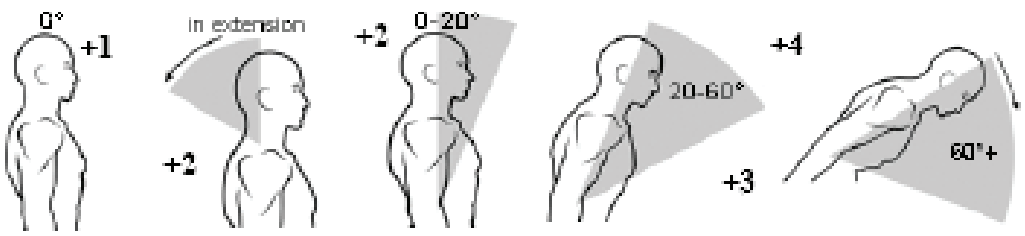

Figure 6. Trunk position.

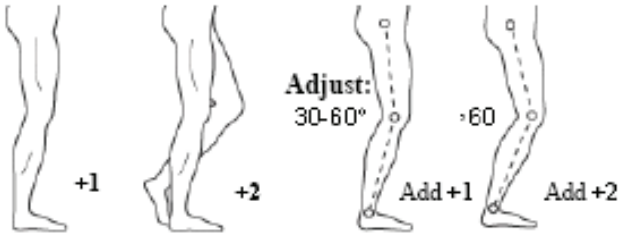

Figure 7. Legs position.

be added as shown in Figure 7. The legs score should be from 1 to 4 points.

After that, the score of neck, trunk and legs should be assigned on table A.

The force or the load score should be added to the score of table A. If the load is less than 5 kg, the score should be 0 points. 5 to 10 kg, the score should be 1 point. For more than 10 kg, the score should be 2 points. If there is a rapid build upload or force, another 1 point should be added. Thus, the A final score should be from 1 to 12 points.

Group B:

Firstly, the upper arm position should be checked separately. If its move 20 degrees forward or backward, the score should be 1 point. If it is more than 20 degrees backward or between 20 and 45 degrees forward, the score should be 2. Between 45 and 90 degrees, the score should be 3 and if it is more than 90 degrees, the score should be 4 as shown

Table 2. Table A

Table A	Neck											
		1				2				3			
	Legs												
		1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	5	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

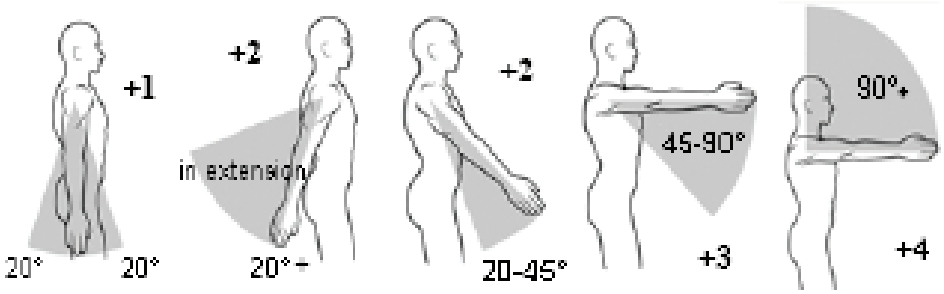

Figure 8. Upper arm position.

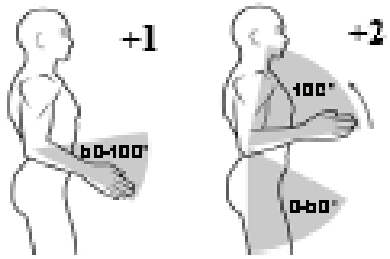

Figure 9. Lower arm position.

in Figure 8. 1 point is added if the shoulder is raised and another 1 point there is an abducting which means that the arm is moving away from the centre of the body. If the arm is supported we subtract 1 point. So, the score of upper arm should be from 1 to 6.

Secondly, if the lower arm is moving between 50 and 100 degrees, 1 point should be the score. 2 points should be the score if the movement is more than 100 degrees, or less than 50 degrees as shown in Figure 9. The score of lower arm should be 1 or 2 points.

Thirdly, if the movement of the wrist is 15 degrees or less upward or downward, the score should be 1 point. If more than that, the score should be 2 points as shown in Figure 10. In the condition of twisting 1 point should be added. So, the score of wrists should be 1, 2 or 3.

Then, the score of arms (upper & lower) and wrist should be assign on table B.

The coupling score should be added to the score of tables. There are three levels for coupling. If it is safe with well fitted handling, 0 points should be added. If the coupling is acceptable but not ideal (fair), 1 point should be added. If it is not acceptable (poor), 2 points should be added. 3 points should be added if there is risk, and the situation is unsafe. So, the total score of B's should be from 1 to 12.

Table C is the table that score of A and B are assign on to come up with the C score.

Figure 10. Wrist position.

Table 3. Table B

Table B	Lower Arm						
		1			2		
	Wrist						
		1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

C score is the final score plus the points of activity which are as following:

- If one or more part of the body is being on hold for more than 1 minute, 1 point to be added
- Small range of repeated actions (4 or more in 1 minute), 1 point to be added
- An action that causes a rapid change in the posture, 1 point to be added

The total score of REBA is from 1 to 15 points and according to the score, an action should be taken depending on the posture's risk level as presented in the following table.

Finally, in case of medium and high levels, the evaluator should come up with solutions and repeat the evaluation again and again (re-REBA) to decrease the risk level as much as possible.

Table 4. Table C

Score A (score form table A +load/force score)	Table C											
	Score B, (table B value + coupling score)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	11	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table 5. Risk levels of REBA

REBA score	Risk level	Action
1	Negligible	Unnecessary
2 - 3	Low	May be necessary
4 - 7	Medium	Necessary
8 - 10	High	Necessary soon
11 - 15	Very High	Necessary now

REBA Calculator

This is an automatic technique that evaluates all the body sections according to REBA assessment and gives detailed feedback showing each part of the body and its risk level.

First, enter the website of the calculator https://industrial.ergo-plus.com/ergoplus/home/eplus and make an account which is free for one month. Then, click add new and choose REBA. After that, choose the position of each body part as shown in Figure 11.

Then, press calculate, and the result should appear as shown on the next side of the page. The result appears on top as shown in Figure 12.

Below the result, detailed information should be provided for each section and its score as shown in Figure 13.

Finally, press save to add the assessment to the account as shown in Figure 14.

REBA calculator is proof of its popularity and how researchers seek to improve it and make it easier to be used by everyone to provide safer environments for all workers. Also, the website provides more automated assessments so the companies can make more evaluations easily to improve their workplace by reducing all the possibilities of WMSDs injuries. The study has been conducted manually and automatically, providing the results of both methods for each posture.

The Comparison of REBA With RULA & OWAS

As the literature studies have proven the importance of comparing techniques in each study. This study provides comparisons between REBA, RULA, and OWAS. REBA study has been done in detail then the results of RULA and OWAS were given to make the comparison for each posture. The technique of RULA is very similar to REBA as shown in Figure 15 [40]. After dividing the body into sections, the score has been evaluated according to the RULA risk category which contains 4 levels.

On the other hand, OWAS considers the simplest technique to examine the whole body. Figure 16 [41] shows how the score is collected. After evaluating the posture according to Figure 16, a force factor is added as 1 point if the load is less than 10 kg, 2 points from 10 to 20 kg, and 3 points for more than 20 kg. Then, specify the risk level from OWAS risk categories that contain 4 levels.

The comparison shows the efficiency of each technique in evaluating the working posture in the gas spring factory and enhances the study by giving more accurate results.

Application

The goal of this article is to analyse the critical working postures in a gas springs factory and after that give some suggestions and solutions to reduce the risks in the workplace. The gas springs are mainly contained in 4 main parts rods, tubes, internal parts, and end fittings or plugs. There are different working positions in the factory because of the variety of production processes. These positions may affect the upper limbs or the lower limbs, so REBA was chosen as the main technique in order to cover the entire body. After evaluating each posture, a comparison with

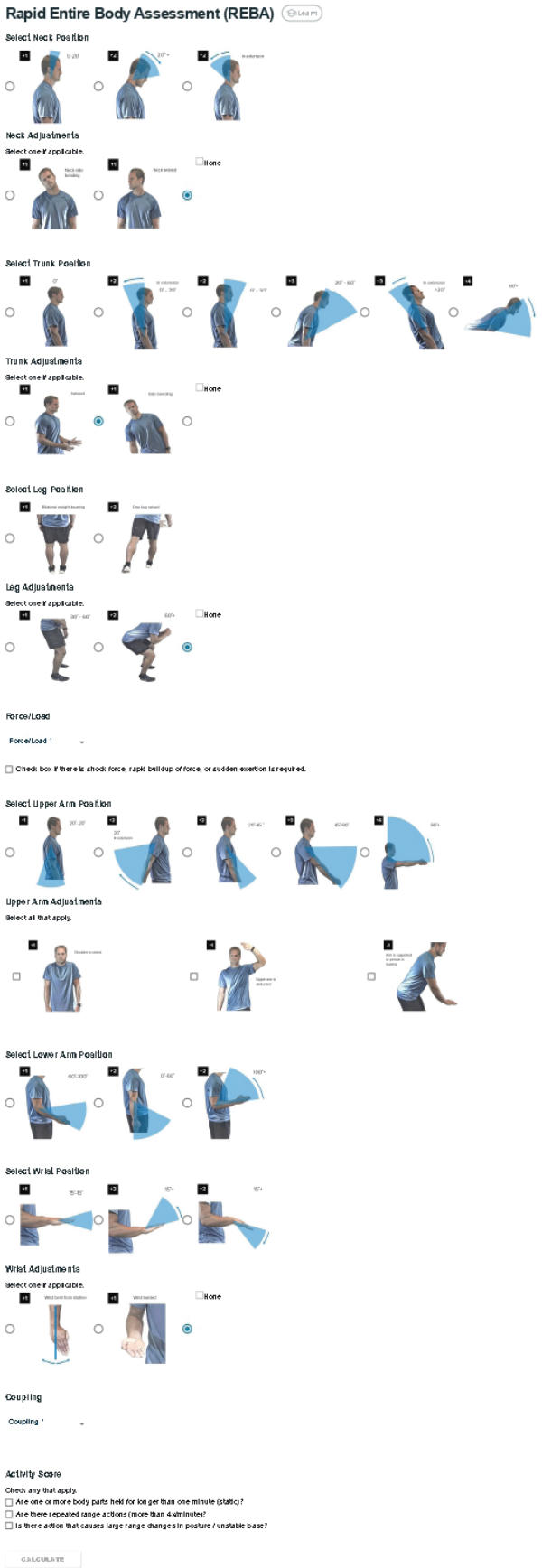

Figure 11. REBA calculator.

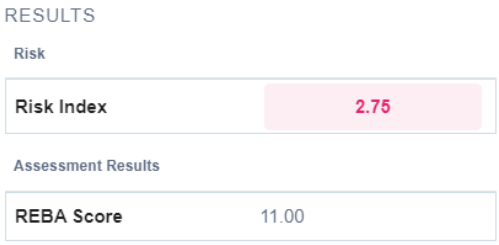

Figure 12. The result of REBA calculator.

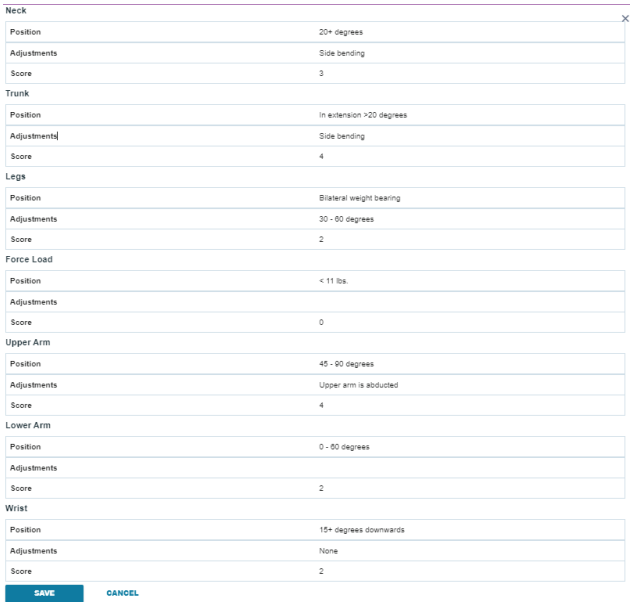

Figure 13. The Detailed Info of Each Section in REBA Calculator.

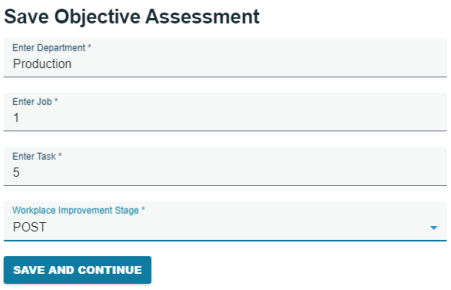

Figure 14. Saving the assessment of REBA calculator.

RULA and OWAS has been made to ensure that the results are as accurate as possible. OWAS was chosen because it covers the whole body too and RULA because according to many studies, it shows the most accurate results regarding the upper body. The data were collected by picturing and filming all the postures of the production processes in the factory. The study covers 15 postures starting from the very beginning process of manufacturing until assembling the

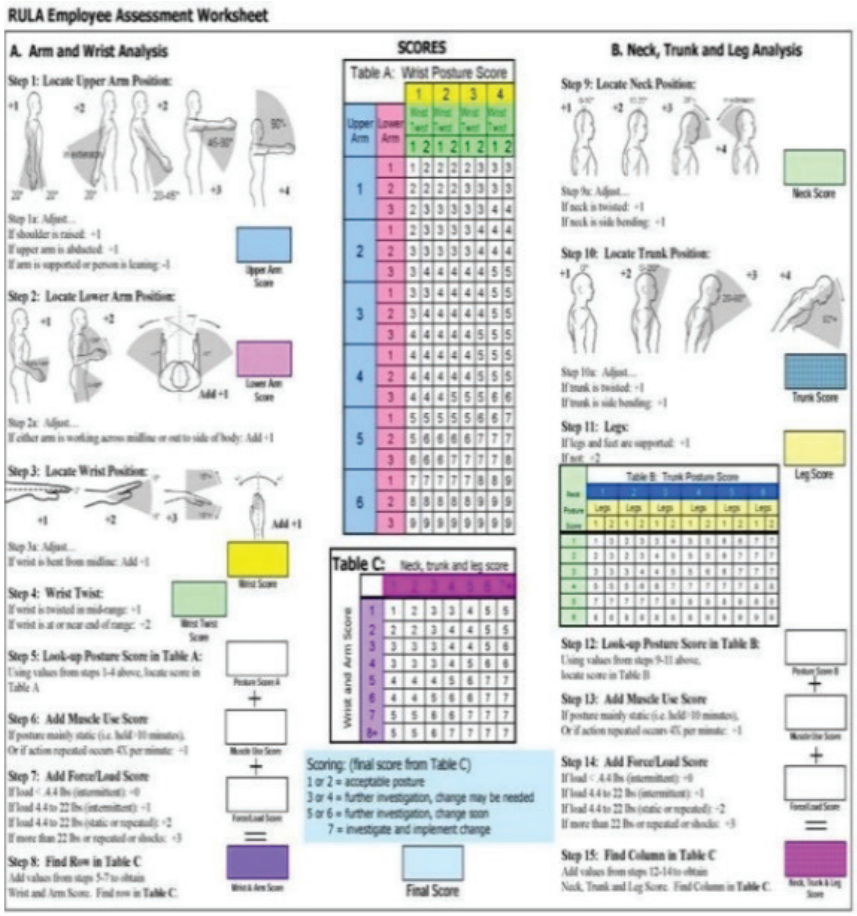

Figure 15. RULA employee assessment worksheet.

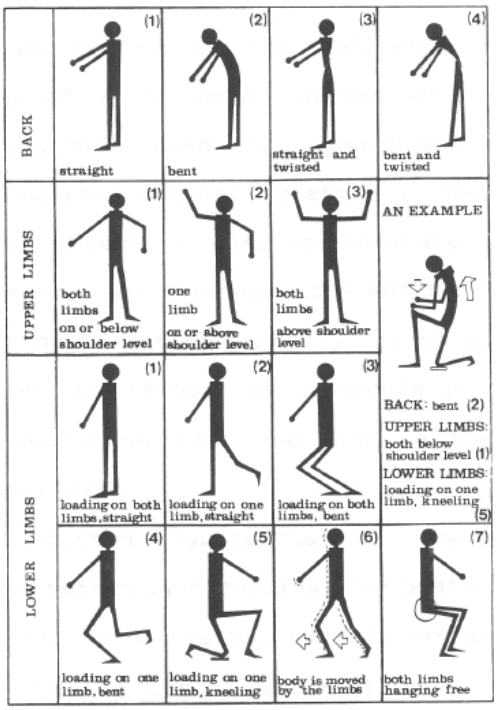

Figure 16. OWAS classification chart.

Table 6. The postures used in the study

Posture no	Posture discerption
1	Rods cutting
2	Rods manufacturing in CNC
3	Tubes preparation
4	Tubes chamfering
5	Rods polishing
6	Rods control
7	Tubes welding
8	Interior components assembling
9	Rods riveting
10	Rolling and closing the gas springs
11	Gas charging horizontally
12	Gas charging vertically
13	Gas springs washing
14	Gas springs painting
15	Assembling the end fittings

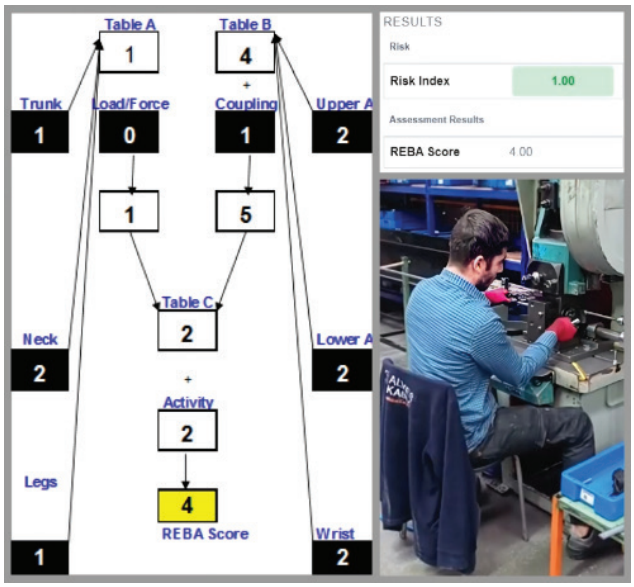

Figure 17. Posture no: 1 with REBA score and result.

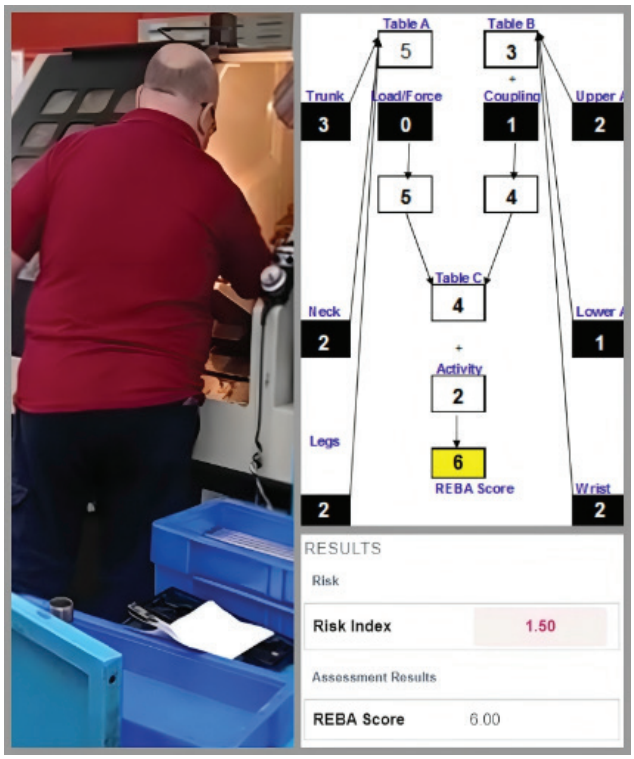

Figure 18. Posture no: 2 with REBA score and result.

end fittings of the products passing through all the production processes in between and Table 6 gives a summarized idea about the postures that the study goes through.

At the end of the section, a general discussion displays the results of each posture and combines them to be able to see the big picture of the study that would be a guideline for many studies in the future. Therefore, it is believed that the output of this application is going to be very effective for the company practically and for researchers theoretically.

Posture No: 1

Rod cutting is one of the essential processes in the industry. As Figure 17 shows, the worker is sitting most of the day cutting the rods and putting them in the boxes next to him.

The REBA score for the position is 4 which seems small but still, it is a medium risk level. Similarly, the RULA score was 3 showing the same risk level. OWAS stated the risk level as normal which is expected from the score of REBA and RULA.

Suggested solution: the button panel of the machine in front of the worker is useless during the process because the worker is using a foot press instead so firstly the panel should be moved because it takes a space and would be an obstacle to reshaping the sitting position. Then, the chair must be redesigned to increase its height and the cutting area should be higher too. The REBA score would decrease from 4 to 3 directly because of the arm movement and the neck position. So, the risk level would be low.

Posture No:2

Shaping the rod end sides via CNC one by one is a common process with stainless steel rods because of their strength which makes shaping them manually very difficult. So, the worker in this position shown in Figure 18 is setting the industrial cart in front of the CNC in a very close way, and on top of it, there are two boxes one is full of unmachined rods, and the other to put the rods in after machining. He is getting the rods and putting them in the machine one by one then he waits until the processing is finished to get the rod back and put another one.

As shown in Figure 18, the REBA score is 6 which means medium risk. Also, the risk level of RULA was the same with a score of 4. While OWAS stated the posture as normal with code 3121. The detail in the upper limb in REBA and RULA gave more credibility to analyse this posture. It doesn't show high risk in REBA and RULA too but still, there is a risk that is supposed to be studied.

Suggested solution: the worker has to work in a sitting position on an adjustable office chair to decrease the risk level by keeping his trunk straight because he would be able to adjust the height level he needs, and the chair should be twisting, not the trunk of the worker. Also, the height of the table should be increased to the same level of machining and be adjacent to the CNC machine so the worker wouldn't have to lie down. Nevertheless, this might be not the best ergonomic solution but the economic one and the best solution in this situation would be using a robotic arm which could be expensive for many firms.

Posture No: 3

In this posture that is shown in Figure 19 the worker is pulling the tubes in order to put them in the cutting machine. It is one of the few postures in the gas springs industry that need strength because of the load. The REBA scoring is presented in Figure 19.

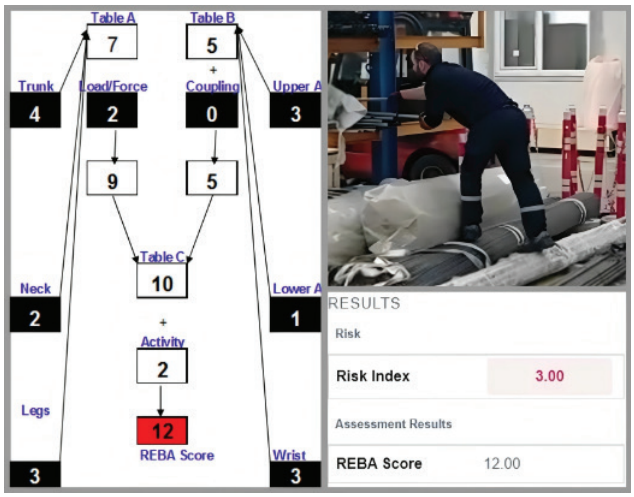

Figure 19. Posture no: 3 with REBA score and result.

The REBA score for this posture is extremely high and it needs an immediate action to change this posture. Also, RULA scored 7 which is the highest score in its range which and OWAS showed that the level of the risk is number 4 the highest in its category too. There is more than one reason causing this high level of risk. Firstly, the place is not clean and full of raw materials which is an obstacle and affects the position of the worker badly. Second, the power needed to pull these heavy tubes, carry them, and move them. So, after the consensus between the three techniques, it became a need for the factory to find a solution for this posture.

Suggested solution: The beginning should be with tidying the area from the raw materials. Then, shelves should be changed to movable ones that move and come to the level of the worker so the load on the legs, trunk, and upper arms wouldn't be as high as it is now. Also, the moving shelves should be designed in a way that the tubes can be taken by the mini electric forklift so the physical load on the worker will be decreased to a very low level.

Posture No: 4

After cutting the tubes, the tubes are taken from the machine to be fed to the chamfering machine next to the cutting machine. The following figure shows the position of the worker who collects around 10 tubes to put in the chamfering machine. The weight of the tubes could be between 5 to 10 kg according to the dimensions and carrying them by curving the back more than 60 degrees is not safe.

The REBA score in Figure 20 shows 7 which is a medium risk level. RULA's score was 4 at the same risk level. OWAS code for this posture is 2131 and it gives a slight risk level. The trunk and arm position play a bigger role in this position and that is the reason for getting medium-level risk.

Suggested solution: the storage box of the machine must be replaced with another one with a lower level of depth and the height of the table below should be increased to reduce the REBA score and improve a bit the position of the trunk and arms.

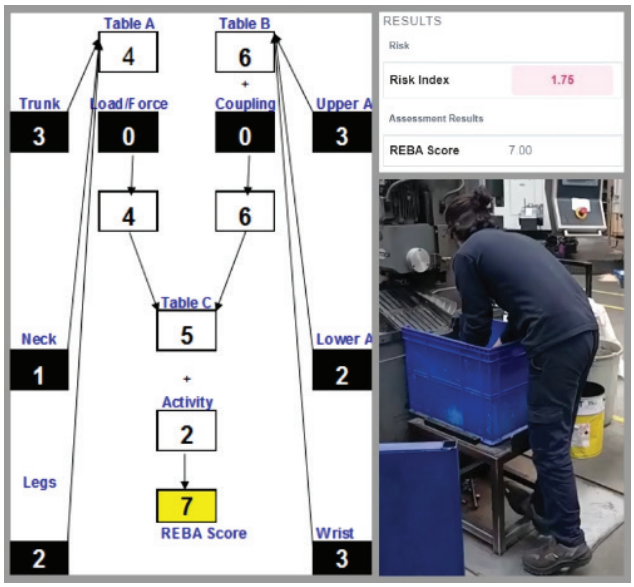

Figure 20. Posture no: 4 with REBA score and result.

Posture No: 5

The posture in Figure 21 shows a worker using the polishing machine to polish the thread of the rods. The worker is taking the rods from his left side and twist his body to polish the rods on his right side. Figure 21 display the REBA scoring sheet of this posture.

The REBA score of the posture is 8 which means a high-risk level that the company should interfere ASAP to decrease that risk. The score of RULA was 5 which needs a soon change also so it is almost at the same risk level as

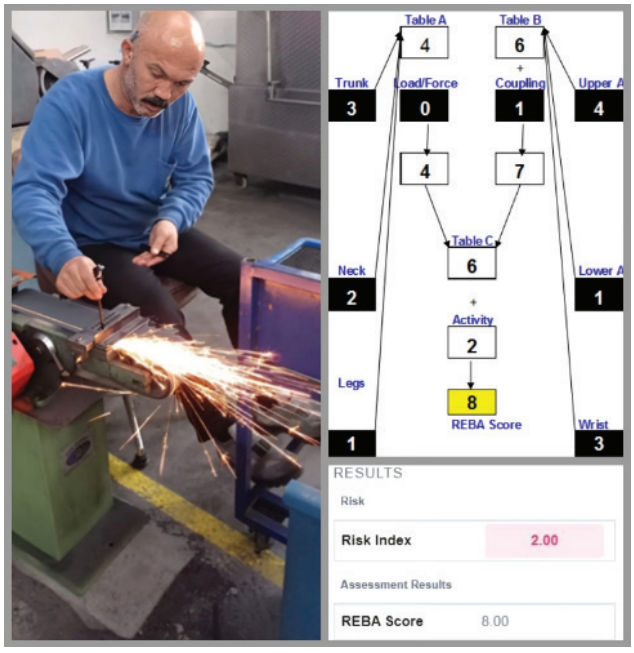

Figure 21. Posture no: 5 with REBA score and result.

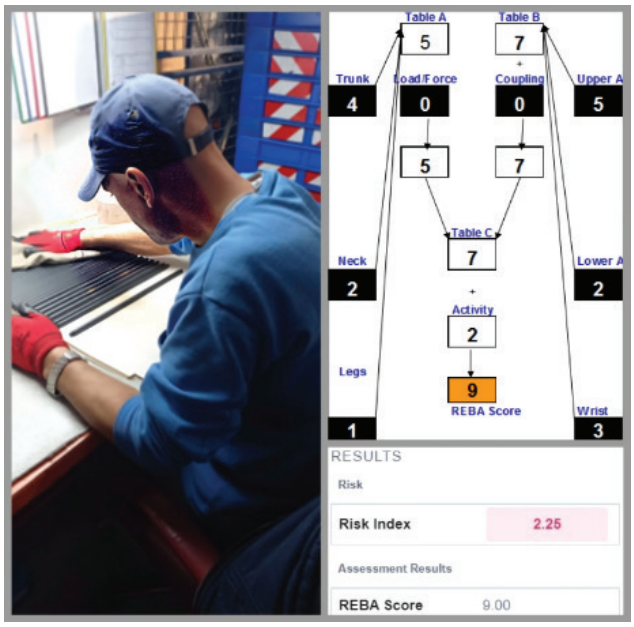

Figure 22. Posture no: 6 with REBA score and result.

REBA. However, OWAS code is 4111 which is risk category 2 (slight risk) with no immediate action. Both REBA and RULA advise rapid action, unlike OWAS results. According to the analysis the risk is high because of the move of the trunk and the upper arm. Suggested solution: the worker must sit in front of the machine with a position of straight legs and the height of the machine should be increased to make the trunk of the worker a straight level, and the rods should be closer to the machine or even in a shelf on top of it so the worker wouldn't need to move and twist his trunk that much. This suggestion would decrease the risk by at least one level.

Posture No: 6

Rods controlling process is a very important process for the gas spring because the surface of the rods should be without defects to guarantee an ideal life cycle for the gas spring. In this process, the worker rolls the rods and checks the defects on them as shown in Figure 22.

The posture scored 9 points and it means again that the risk level is high. RULA scores 6 for this position so it corresponds this time too with REBA that there is a high-risk in this posture. OWAS code here is 2211 which leads to a slight risk level. In this posture, the trunk position should be modified.

Suggested solution: an angular stand must be put on the table to roll the rods on to keep the trunk of the worker in straight shape so the risk would be reduced.

Posture No: 7

Welding the end plug on the tube is one of the most common activities in this industry. In the posture in Figure 23, the worker is taking the tubes from his left side and twisting his body to weld them in the welding machine on his right side.

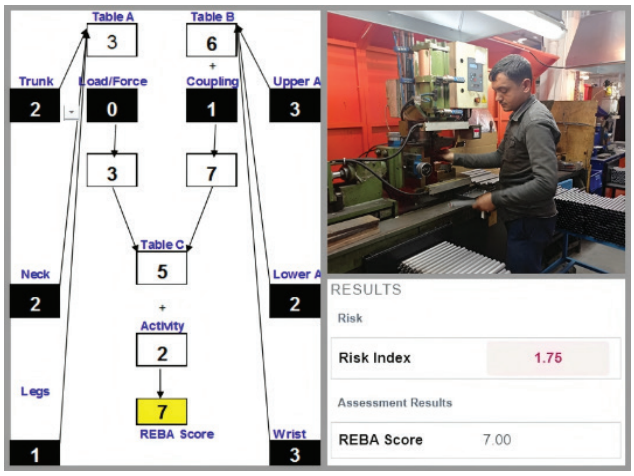

Figure 23. Posture no: 7 with REBA score and result.

As Figure 23 shows the REBA scoring, the score is 7 which means a medium risk level that doesn't need immediate action. RULA score is 4 and it also means no need for rapid change. OWAS code was 3121 which means that the position is normal in risk level 1. However, keeping twisting the body in that way the whole day might cause a WMSD injury in the long term especially because of the load on the waist.

Suggested solution: although there is no need for immediate action here, the observations show that the worker should feed the machine without twisting his trunk by putting all needed components adjacently next to the machine, which would make the posture totally safe according to REBA and RULA as well.

Posture No: 8

Many of the gas springs have complex interior components so before using them they have to be gathered as shown in Figure 24. The worker gets the interior parts one by one and puts them on top of each other.

Figure 24. Posture no: 8 with REBA score and result.

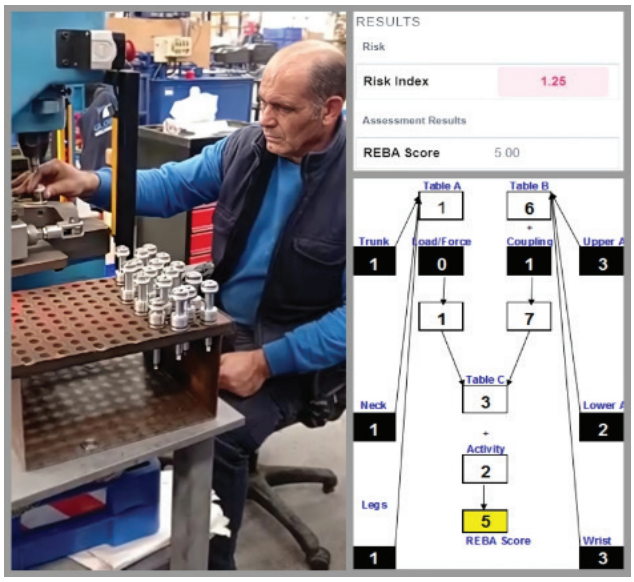

Figure 25. Posture no: 9 with REBA score and result.

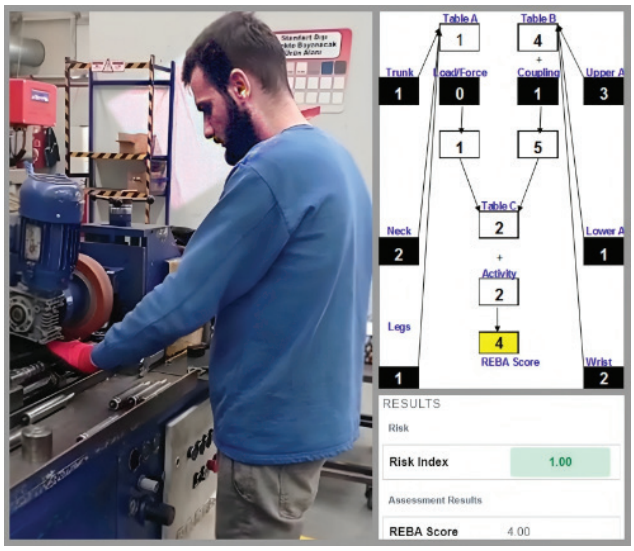

Figure 26. Posture no: 10 with REBA score and result.

The REBA score for this posture is only 3 which means a low-risk level. RULA also gave a score of 2 which means that's an acceptable posture. OWAS result states that it is a normal position too.

Suggested solution: the worker should work in a sitting position to make the posture safer, especially for the neck.

Posture No: 9

Riveting is the process when the worker compresses the interior components of the gas springs on top of the rod as shown in Figure 25. He takes the rods from his right side and puts them in the machine to compress them with their components to put them on his left side.

5 points were the score for this position. It is not a dangerous level but still at the medium level. RULA score is 4 at a medium level too. On the other hand, OWAS shows a normal level with 1111 code due to the fact that there is no detailed analysis for the arms and wrists positions, unlike REBA and RULA which scored medium level risk because of that.

Suggested solution: the stand of the machine is thin so it can be positioned in between the legs of the workers and by increasing the height of the chair to be on the same level as the table the risk level reduces. Because as REBA results show, the high risks came from the load on the arms so increasing the height of the chair would improve the position of the arms.

Posture No: 10

The rolling and closing process is one of the unique processes of the industry of gas springs. After putting the rods in the tubes, the worker takes them to put them in the machine of rolling and closing to be assembled as shown in Figure 26.

This posture scored 4 points. So, the risk level is medium. RULA also scored 4 and that's the same risk level. OWAS code for this position is going to be 1121 and this code gives a result of a normal position with risk level 1. The upper arm position and rapid change in the position of the worker to get the parts caused the score of REBA and RULA.

Suggested solution: it would be difficult to solve the position of the upper arm but in order to reduce the risk level, ensuring that the parts are very close to the machine, so the worker gets them without rapid change in his position reduces the activity points. Also, putting a sensor to pause the machine automatically while approaching it could reduce the coupling points and decrease the risk level as well.

Posture No: 11

In this posture, the worker is charging the gas springs with gas as the following figure shows. Charging with gas is one of the unique processes for this industry. Also, it is one

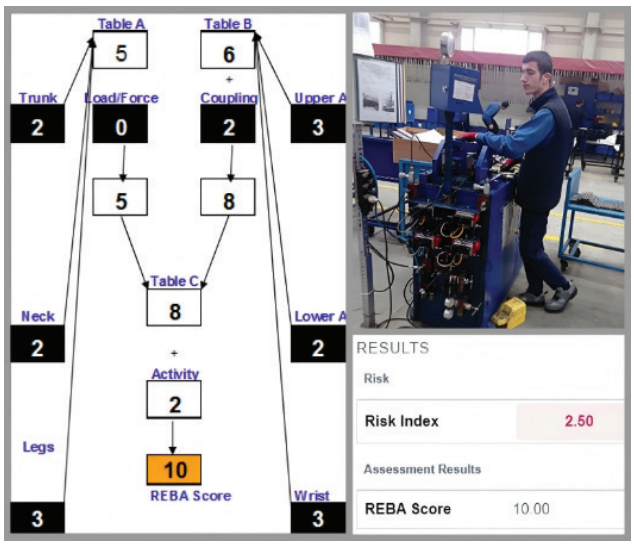

Figure 27. Posture no: 11 with REBA score and result.

of the daily processes that doesn't stop at all. The worker here is getting the gas springs next to him and putting them in the charging machine one by one.

The REBA score shown in Figure 27 is 10 so there is a need to interfere because it is a high-risk level situation. However, RULA gave a lower level than REBA this time with a score of 4 a need to change but not immediately. This difference between them that time is because of the legs' positions. RULA doesn't zero in on the position of the leg because it is interested more in the upper limb of the body. The result of OWAS was normal position and this result happened because OWAS doesn't evaluate the upper limb in detail as the lower limb. So, RULA and OWAS are just the opposite in evaluating this posture, one focuses more on the upper limb, and the other one on the lower limb. Thus, REBA gave a better result for this posture.

Suggested solution: maybe there won't be a fast solution for the position of the leg because of the leg press button, but the height of the machine must be increased slightly to improve the positions of the trunk and neck without putting too much extra load on the arms so, the risk of the posture would be reduced. Also, it would be more economical to make an anthropometric measurement analysis to check if there is another worker with more suitable body measurements for the machine.

Posture No: 12

The gas filling has another position which is filling in the vertical machine as shown in Figure 28. The worker puts the gas springs in the vertical gas filling machine and after that takes it back and puts another one.

The REBA score shows a middle-risk level which is better than the horizontal gas filling machine which gave a high-risk level. RULA scored 4 which is at the same risk level. OWAS risk level was 1 as normal position. The upper arm position is the reason why REBA and RULA scored higher than OWAS.

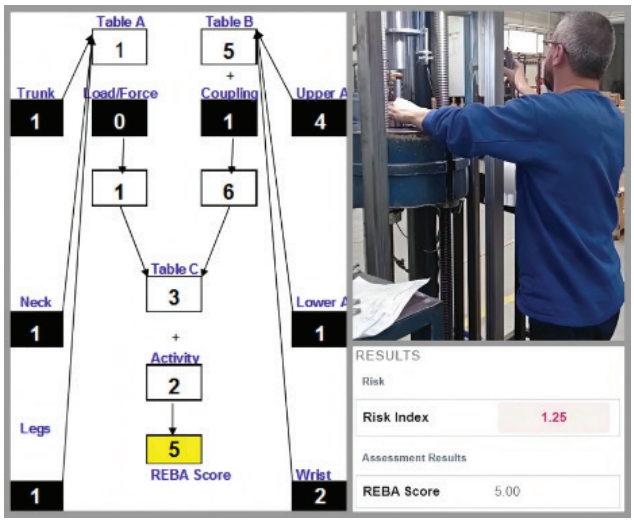

Figure 28. Posture no: 12 with REBA score and result.

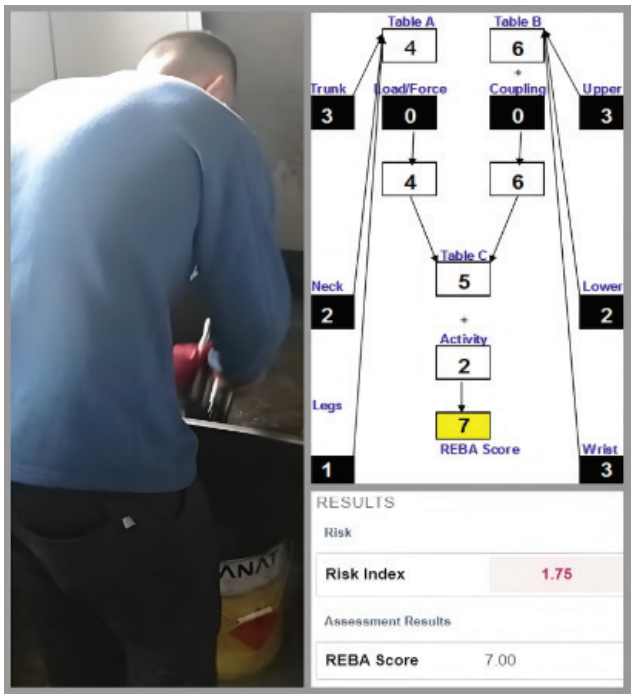

Figure 29. Posture no: 13 with REBA score and result.

Suggested solution: the worker has to stand on top of a small stage, so the upper arm would be in a comfortable position to decrease the risk level.

Posture No: 13

Gas springs should be washed very well before painting in order to have a well-painted gas spring at the end. So, in this posture the worker is putting the gas springs in water, washing them, and shaking them off as in Figure 29.

Figure 29 displays that the posture scored 7 and the risk is in medium level. However, the score of RULA is 5 which means that there is a need to interfere. On the other hand, OWAS agreed with REBA that there is no need for risk level 2. In this posture, what made RULA more accurate is because of the assessment of the wrist because it was shaking too much.

Suggested solution: to decrease the RULA score, a water gun must be used to solve the wrist problem and decrease the score of RULA to the safe side.

Posture No: 14

The painting machine in the factory is an automated robotic machine. Thus, the workers only need to hang the gas springs on the hangers as shown in Figure 30. Most of the gas springs need to be painted that's why the workers of the painting department keep working in this position all the working days.

The REBA score for this Position is 9 again a high-risk level as shown in Figure 30. RULA also supported this result with a score of 5 which means the same risk level on RULA's scale. The OWAS result was shocking because the code was 1321 which gives risk category number 1 on the OWAS scale to describe the posture as normal. This result occurred due to the fact that OWAS doesn't focus too much on the

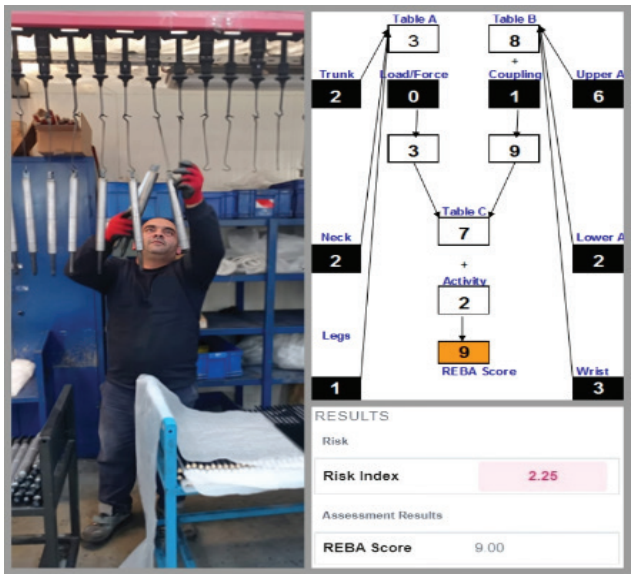

Figure 30. Posture no: 14 with REBA score and result.

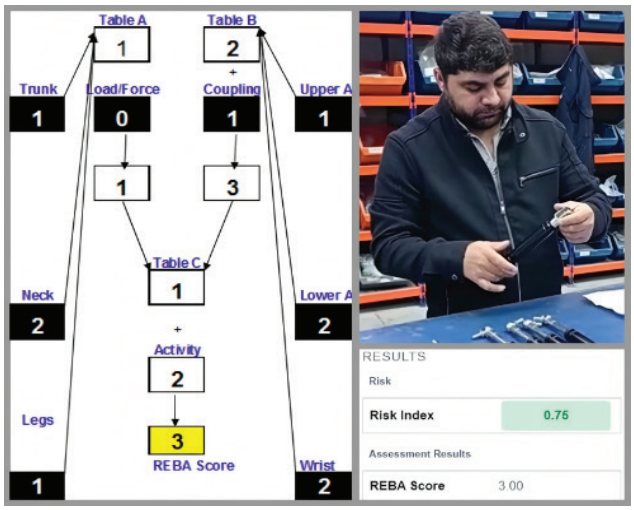

Figure 31. Posture no: 15 with REBA score and result.

position of the upper arm in detail and also if the trunk has a backward move. On the contrary, REBA and RULA scored highly because they take these positions into consideration. The upper arm is in a very risky position because it raises to its maximum level with the shoulders too and the arm is abducted because it moves beyond the centre of the body.

Suggested solution: the hangers would be moveable up and down until they came to the same level as the worker so workers can hang with a straight trunk level and their upper arm won't be at risk because of raising it the whole day.

Posture No: 15

Assembling the end fittings is the final step of making a gas spring. Usually, it happens on a table where the worker is getting the end fittings and assembling them on one side or on both sides.

A score of 3 was the REBA score for this posture which means a low-risk level. RULA's result was an acceptable posture too with a score of 2. OWAS agrees also with REBA and RULA for this position by stating the position as normal.

Suggested solution: working should be sitting in this process to lead to a more comfortable position for the neck without raising the arms.

RESULTS AND DISCUSSION

After applying REBA, RULA, and OWAS on 15 postures, the following table displays the result of each posture for the three techniques.

Table 7. Results analysis

	REBA		RULA		OWAS	
Posture No	**Score**	**Risk Level**	**Score**	**Risk Level**	**Score**	**Risk Level**
1	4	Medium	3	Medium	1	Normal
2	6	Medium	4	Medium	1	Normal
3	12	High	7	High	4	High
4	7	Medium	4	Medium	2	Slight
5	8	High	5	High	2	Slight
6	9	High	6	High	2	Slight
7	7	Medium	4	Medium	1	Normal
8	3	Low	2	Low	1	Normal
9	5	Medium	4	Medium	1	Normal
10	4	Medium	4	Medium	1	Normal
11	10	High	4	Medium	1	Normal
12	5	Medium	4	Medium	1	Normal
13	7	Medium	5	High	2	Slight
14	9	High	5	High	1	Normal
15	3	Low	2	Low	1	Normal

As shown in Table 7, REBA and RULA almost have the same results, but OWAS mostly gave lower risk levels. 53.33% of REBA and RULA results were Medium-Risk Level. While 33.33% of them were declared as High-Risk Level. Only 13.33% were Low-Risk Level. On the other hand, OWAS stated 66.67% of the postures as Normal Position, 26.67% as Slight-Risk Level, and only 6.67% as High-Risk Level. One of the reasons why REBA's results are above the low mostly is the activity section. In almost all postures one or more section of the body is stable for a long time and the others are moving rapidly so the score of the activity section was always 2 for all postures that had been examined.

Due to the fact that RULA deals only with the upper limb of the body, REBA was more realistic than RULA for analysing the postures that had loads on the legs. Nevertheless, the analysis of RULA for wrists was more accurate but this does not negate the fact that RULA wasn't suitable for some postures because of the load on the lower limb as mentioned. Therefore, it is suggested to use REBA or RULA (in case of the absence of the importance of the load on the lower limb)to analyse these postures and similar ones regarding their precise results and the high ability to define sections of the body at risk. Oppositely, it is not recommended to use OWAS for the similar postures because of their complexity and OWAS generally could come up with better results for simpler postures, so it showed an inability to detect risks for the examined postures in this study. In this case, a hypothesis was made about the bond between the techniques. The techniques were gathered in pairs (REBA-RULA, REBA-OWAS, and RULA-OWAS) and a chi-square test was conducted on the results of the risk levels. The categories were stated as low-risk, medium-risk, and high-risk, as in Table 7. The results of the chi-square test were as Table 8 shows.

According to the results of the Chi-Square test, the P value of the pairs of REBA-OWAS and RULA-OWAS is less than 0.05 which rejects the hypothesis of having a bond or connection between OWAS and the other technique. On the other hand, for the pair of REBA-RULA, $P > 0.05$ which assures the relation between REBA and RULA in this case and confirms that RULA could be an effective alternative for REBA in this study. To approve the connection between REBA and the other techniques, a correlation analysis was made and the result of REBA-OWAS was 0.468 but REBA-RULA was 0.844 which is a very high correlation and a positive relationship. Therefore, it can be stated clearly that REBA and RULA are very suitable to be conducted to evaluate the type of postures in this study regarding the sensitive results they showed in contrary to the results of OWAS. In brief, the comprehensiveness of REBA for the entire body is the difference between it and RULA, and dealing with the complex postures in detail is what differentiates REBA from OWAS, and that's why using REBA as the main technique was the best choice.

Table 8. Chi-square results

Chi-Square	p
REBA-RULA	0.264
REBA-OWAS	0.009
RULA-OWAS	0.009

Comparing the results of this study with the studies in the literature review, it achieved the same target by suggesting solutions to decrease the risk level of the working postures from the high levels to the low levels. However, this study worked on 15 postures which is much more than the other studies giving this study a privilege over the others as an additional advantage. In general, the risk level of most of the postures was medium which means that the workers' safety in the factory is not threatened under high-level hazards. But, decreasing the medium to low-risk level is going to be the goal for the company and by taking the suggestions into consideration and re-REBA, the company could achieve that target. The company started solving these issues by looking for movable shelves to decrease the risk of posture no: 3 which scored the highest risk. This action displays the significance of applying ergonomic assessment in factories to minimize risk levels.

CONCLUSION

In conclusion, this article displays the importance of applying the analysis techniques that detect if the workers are exposed to WMSDs injuries. REBA is one of the most popular and effective techniques to analyse these kinds of risks. This paper proved that efficiency either by the literature review which showed how much is REBA used and trusted in many sectors all over the world or by the application which was conducted in a gas springs factory. 15 postures were analysed in this paper using the classical REBA methodology and REBA calculator. Also, a comparison between REBA, RULA, and OWAS was conducted to enhance the study and its results. After the application, it was recommended to rely on REBA or RULA's results more than OWAS which couldn't deal with these postures effectively. The results of OWAS didn't highlight the risks in this study but it might be more suitable for different studies. According to REBA's results, 53.33% of the postures were declared as medium-level risk so the risk situation of the factory can be improved with some simple solutions as suggested. It would be beneficial to employ both REBA and RULA for the situations' reassessment after implementing the suggested solutions or different ones to guarantee that the possibility of WMSDs injuries would be dramatically decreased. It is very significant to get used to making REBA and re-REBA always to develop the environment of the workplace to be safer for the workers. All supervisors and managers should be trained to conduct these assessments because they are easy to apply, fast to be conducted, and

accurate in analysis. The suggestions given in the study are very informative and helpful, but the absence of the engineering design dimension could be considered as a limitation in this paper. Thus, some postures of this study can be chosen to design a physical solution for them in future research such as designing an ergonomic chair for posture number 2. Moreover, it was interesting to discover a tool such as the REBA calculator by ErgoPlus company that makes risk analysis much easier. This proves the importance of technology to improve classical methodologies. The time spent observing, filming, and recording is another obstacle or limitation, especially for analysing a huge number of postures, and technology should interfere to solve this issue too. Therefore, at the end of this paper, I recommend more studies in that field using high-tech like AI technology. For instance, security cameras in the workplace can be developed in future research to be able to analyse all the movements of the workers and report for risky postures automatically after feeding the cameras system with the needed data from previous studies of REBA, RULA, OWAS ..etc such as this case. Lastly, it will be a relief to see that all the workplaces are secured with the lowest possibilities of injuries and accidents.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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