Mechanical Engineering – Scientific Journal, Vol. **43,** No. 2, pp. 83–92 (2025)
Number of article: 696
In print: ISSN 1857–5293
Received: November 24, 2025
On line: ISSN 1857–9191
Accepted: December 17, 2025
UDC: [621.791-05:613.65]:331.101.1
https://doi.org/10.55302/MESJ2543283c

Original scientific paper

DETERMINING THE DEGREE OF ACCEPTABILITY OF THE WORKING BODY POSTURE OF WELDERS THROUGH THE APPLICATION OF THE RULA METHOD

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A b s t r a c t: The purpose of this research is the determination of the degree of ergonomic acceptance of the working body posture of welders in a production plant from the metal processing industry in North Macedonia. The ergonomic analysis is done through the implementation of the Rapid Upper Limb Assessment (RULA) method. The quantitative score of the angles of the joints and working body postures is determined, with added additional scores for overload and muscle activity. Final scores for each welder are compared to four action levels showing the degree of acceptability of the working posture, the level of needed intervention, and a time frame for commencing risk control. The results indicate that welders are exposed to high risk work-related upper extremity musculoskeletal disorders (MSDs). Therefore, proposals for reducing the degree of risk from MSDs are given aimed at adjustments and adaptation of the equipment to the anthropometric characteristics of the individual welders.

Key words: welding; working posture; ergonomics; RULA; musculoskeletal disorders

ОДРЕДУВАЊЕ СТЕПЕН НА ПРИФАТЛИВОСТ НА ПОЛОЖБАТА НА ТЕЛОТО НА ЗАВАРУВАЧОТ ПРЕКУ ПРИМЕНА НА МЕТОДОТ RULA

А п с т р а к т: Целта на ова истражување е да се утврди степенот на ергономско прифаќање на држењето на телото при работа на заварувачите во производствен погон од металопреработувачката индустрија во Северна Македонија. Ергономската анализа е извршена преку имплементација на методот за брза процена на оптоварувањето на горните екстремитети (RULA). Определен е квантитативниот резултат на аглите на зглобовите и држењето на телото при работа, со додадени дополнителни резултати за преоптоварување и мускулна активност. Конечните резултати за секој заварувач се споредени со четири нивоа на дејствување што го покажуваат степенот на прифатливоста на држењето на телото при работа, нивото на потребна интервенција и временска рамка за започнување со контрола на ризикот. Резултатите покажуваат дека заварувачите се изложени на мускулно-скелетни нарушувања (МСН) на горните екстремитети произлезени од работата со висок ризик. Дадени се предлози за намалување на степенот на ризик од МСН, насочени кон приспособување и адаптирање на опремата според антропометриските карактеристики на поединечните заварувачи.

Клучни зборови: заварување; работна положба; ергономија; RULA; мускул-скелетни нарушувања

1. INTRODUCTION

Ergonomics, formally defined, is a scientific discipline that is dedicated to understanding the interactions between people and the various elements of a system. Through the application of theory, principles, data and methods, it ensures the optimization of the human's well-being and the system performance.

A system is a set of interconnected elements that, through symbiosis, aim to achieve certain goals, and work is a set of interconnected activities, tasks, people, tools, resources, and processes combined to achieve a common goal, in order to produce a physical product or provide a service [1]. The goal of applying ergonomics in a production system is to create a proactively designed workplace in order to celiminate the risks of injury, pain, discomfort, and demotivation [2] and to create an environment that is designed in compatibility with human needs [3]. Ergonomics is aimed at better integrating the person into the system [4]. The successful adaptation of a work task to the worker depends on the degree to which certain important criteria are met, such as functional efficiency and productivity, comfort, health and safety of the worker, and quality of life outside the work environment [5]. In short, almost any aspect of work where a person is involved in performing a work activity and task can be the subject of ergonomic analysis [2].

Every person who has a managerial position in a production system wants the constituent units as subcomponents to function in symbiosis with the greatest possible ease and efficiency. However, in the case when a part of that system is a person in the role of a worker, the performance and results of the system as a whole can vary and differ depending on the current and daily physical fitness of the worker. Although people have great potential to bring flexibility, innovation and skills to solve various production problems, they are also exposed to the risk of developing work-related musculoskeletal disorders (MSDs) that arise from performing physical activity that overloads the human body. The first signs of such overload include discomfort, physical pain and repetitive injuries. Work-related MSDs include injuries and illnesses that are caused by harsh working conditions [6] and are usually not caused by acute events but develop slowly over time due to repeated use of the same body part group or microtrauma [7] and can be prevented or delayed [6]. Many of these disorders are caused by static postures, sometimes accompanied by intense exertion or repetitive movements that need to be maintained intensively for most of the working day [8]. Incorrect body posture can lead to local mechanical stress on muscles, ligaments and joints [9] and permanent damage to body tissues [10]. Extreme or uncomfortable postures are recognized as one of the main risk factors for the occurrence of MSDs [8]. MSDs of the back, upper and lower extremities are a cause for serious concern, as they are the most common cause of work-related absenteeism and represent an industrial problem [8], but the application of ergonomic principles reduces the possibility of MSDs [7]. Correct body postures at work significantly decreases the risk of MSDs and has a positive effect on the efficiency and effectiveness of the worker.

Therefore, manufacturing systems and their management should focus on applying the required methods and tools for ensuring the workers are healthy and efficient. The approach that a manufacturing system takes to addressing ergonomic aspects of work can depend on many things, such as the size and shape of the organization itself, past experience, and the level of knowledge of ergonomic methods and tools. Incorporating ergonomic knowledge early in the planning process and understanding ergonomics as a way to reduce costs by maintaining a healthy workforce are characteristics of a proactive approach. A reactive approach is characterized by not addressing problems and risks until the consequences of unergonomic work begin to appear, such as pain and injury among workers, resulting in absenteeism [2]. There are several methods that can be applied for ergonomic evaluations in the workplace, among which is RULA (Rapid Upper Limb Assessment).

This research focuses on the application of the RULA method in an ergonomic study of the working posture of welders in a specific production facility in the metalworking industry in the Republic of North Macedonia. The RULA method was chosen to help provide guidance for the middle and senior management to eliminate ergonomic entropy as an irregularity in the functioning of the work system and avoid the possible incorrect use of ergonomic principles that lead to fatigue, reduced productivity, and sometimes injury at the workplace.

2. BACKGROUND AND MOTIVATION FOR STUDY

In order to expand knowledge on the chosen topic, a research and study of relevant scientific literature in the field of ergonomics and specific case studies where the application of the RULA method is encountered was conducted. The research was focused on case studies in the field of production, conducted in various countries around the world from 2010 to the present. Many examples were reviewed and a part of them, related with welders, are analyzed in this section. The goal was to review possible applications of RULA, and search for applications in companies in North Macedonia.

Many of the reviewed researches were associated with assembly line tasks, focusing on identifying occupational risks and worker safety in the manufacturing industry through interviews, observations, video recordings and the application of the RULA method, highlighting the significant risks faced by workers, which require urgent changes, and investigating work-related MSDs among workers [11, 12, 13, 14]. Ergonomic evaluation tools are mostly applied where repetitive working postures occur to estimate the musculoskeletal load and risk of MSDs [15, 16, 17, 18]. The application of the RULA method was found in many other cases to evaluate and improve the ergonomics of various production processes, exploring the key role of ergonomics in improving productivity and quality and the relationship between work methods and workstations [19, 20, 21, 22].

More precisely, in the field of welding-related tasks, one study assesses the risk of musculoskeletal injuries in steel welding through field observation and research on welders' movements while performing different work tasks. Using the RULA method, the aim was to identify the factors that contribute to the occurrence of MSDs. The analyses highlight that these disorders are the result of incorrect working postures. Elements of the workplace, welding method and work environment factors determine the degree of disorders, with less skilled welders being found to be at higher risk of developing MSDs. The study suggests the implemention of periodic ergonomic reviews of facilities, workstation design and work practices, while emphasizing the importance of proper training of welders, in order to recognize and report symptoms of MSDs early, and the need for proper ergonomic design adapted to different welding positions [23].

Another study focuses on improving the ergonomic conditions of welders on assemblies in the automotive industry. Using the RULA method and computer-aided design software, an analysis of the existing welding process was performed, critical ergonomic problems were identified, and an ergonomic intervention was created by designing a hand support for the workers. The implementation of the support resulted in improved results and a change in the risk level from high to medium, indicating increased well-being among the welders. The analyses highlight the successful reduction of ergonomic risks obtained through the implementation of the optimized device, which was designed based on feedback from the workers [24].

One more research aims to assess and analyze the working posture of workers in a small manufacturing company, focusing on various work tasks such as material handling, cutting, drilling, welding and grinding. A questionnaire on musculoskeletal discomfort was administered workers, and it was found that the most prominent body areas with musculoskeletal discomfort were the lower back, upper back, shoulder and neck. Ergonomic risks were assessed using tools such as RULA and other methods, with the results of the RULA method showing that most workers (33.33%) needed additional ergonomic investigation and changes in their working posture, and 24.07% needed urgent ergonomic intervention and immediate changes. The results of the study prove that workers predominantly perform work tasks in an incorrect body posture, primarily due to a lack of ergonomic awareness. The study recommends changes in body posture and work-rest cycles, implementation of ergonomic interventions and appropriately designed workstations to mitigate risks [25].

The results of the review of the scientific literature and specific case studies in the field of production where ergonomic research has been applied, indicated that the application of the RULA method provides quick, simple and visual indications of the level of risk and the need for action [26]. The method does not require special equipment to provide an assessment of body postures along with muscle functions and external loads experienced by the body. This allows to perform assessments without additional costs. Since it is an observational analysis, the assessments from the method can be made at different workplaces without disrupting the work process and workers. Researchers using this method do not need previous skills in observation and ergonomic assessment [27].

More importantly, the review revealed a lack of application of the considered method in ergonomic research in companies from the manufacturing industry in our country, North Macedonia. Unfortunately, the reality is that in our country there is a lack of such, or similar, ergonomic research in other industries and systems. This lack means that systems take a reactive approach to work that is characterized by not solving problems and risks until the consequences of non-ergonomic work begin to appear, such as pain and injuries in the workforce that can result in absences. This is something that needs to change, i.e., at every organizational level, those responsible should have knowcledge of ergonomics and encourage its correct application in the direction of continuous improvement and correct business practice in which the value of a healthy workforce is proactively supported. Their knowledge of the needs and abilities of workers should result in feasible changes to the elements of the system that should reduce or eliminate risks.

Such shortcomings arising from insufficient ergonomic research, are a motivation for conducting research using the ergonomic method for rapid assessment of the upper extremities in order to identify and assess the risks arising from the incorrect implementation of ergonomic elements. The independent analysis of the current state of the workplaces in the company is additionally motivated by their own understanding of the economic benefits of the correct integration of the workforce into the system. An additional motivating factor for the application of the ergonomic method is the education of all involved in the system and the encouragement of thinking about the importance of ergonomics and its impact.

3. MATERIALS AND METHODS

This research was done in a part of a production plant in a specific company from the metal processing industry in North Macedonia. The TIG welding operation was chosen as the subject of ergonomic research, in which, through several years of work experience in the company and observation of the process, incorrect body postures of the welders were often observed. During observation, it was established that the TIG welding operation was performed in a sitting position 75% of the time, and the remaining 25% of the time was filled with occasional movement or standing of the welders. Therefore, the method for rapid assessment of the upper extremities (RULA) was chosen to be used as a tool for assessment of the risks arising from the working posture that was present when welding the joints of the assemblies.

The RULA method [27] was developed by ergonomists Lynn McAtamney and Nigel E. Corlett in 1993 [26], then members of the Institute of Occupational Ergonomics at the University of Nottingham, England [7]. The method is a type of observational tool [3] that can be used as part of an ergonomic assessment of workplaces [26] to examine workers' exposure to the risk of work-related MSDs of the upper limbs [28]. The method was developed to provide an analysis where the work places physical demands on the trunk, neck and upper limbs [26]. The focus of the method is to analyze the working posture of the person [7] and is used in work tasks that are characterized and defined as sedentary [27] in which the upper body is heavily engaged [26], and the worker performs work tasks in a sitting position for 75% of the time (6 hours out of an 8-hour working day), and the remaining 25% (2 hours out of an 8-hour working day) is in occasional movement or standing. During the analysis, using diagrams of different body positions, a quantitative assessment of the angles of the joints and the body posture is made, with additional assessments of the load and muscle activity [26]. By recording the observational elements, a final assessment is obtained, i.e., the risk is calculated in a score from 1 (low) to 7 (high) [27]. These ratings are compared to four action levels that indicate the level of intervention needed to reduce MSDs [3] and provide an indication of the time frame within which it is reasonable to expect risk control to begin [27].

Participants

Before the ergonomic research began, the welders were introduced to the objectives and application procedures of the RULA method. All 5 welders currently present in the company gave an oral consent, which was then expressed in writing by completing individual consent statements. The respondents were informed about the details of the research and provided written consent.

In addition, a questionnaire on MSD symptoms was completed by each welder, from which data on the welders and certain anthropometric measures were extracted (Table 1). The standard working hours for all welders are 40 hours per week.

T a b l e 1

Data for the study participants – welders

ID number in the company	Gender	Age (years)	Height (cm)	Weight (kg)	Work experience in the company
101	M	49	172	120	24 years and 5 months
102	M	49	180	105	6 years and 3 months
103	M	27	173	75	4 years and 7 months
104	M	22	173	65	2 years and 8 months
105	M	23	170	61	1 year and 7 months

The welders' identification (ID) numbers assigned upon their employment in the company were, accordingly, used as identification numbers in the ergonomic research (a welder with identification number in the company 101 corresponds to welder 101 in the research).

Environment

The design of the workplaces of the welders consists of a chair, a workbench and a vice (Table 2). Some of the work elements (the welding device, electrodes, additional materials and work orders) are usually placed on the workbench. The vice, which is a clamping device, is attached to the workbench with two sides between which the assembly/product is clamped during welding. The chairs and workbenches are static without the possibility of adjustment, and the vices are movable and can rotate around their own axis. The workplaces are safely and appropriately separated by partitions.

Table 2

Data on the design elements of welders' workplaces

Work place	Height from floor (cm)		
	Chair	Table	Vice
Welder 101	600	840	1080
Welder 102	620	840	1070
Welder 103	600	840	1090
Welder 104	610	840	1060
Welder 105	600	860	1085

Procedure

The whole procedure was based on the steps according to the RULA method:

- Observation and selection of the working position and posture for further assessment;
- Assessment of the working posture;
- Determining the final score for the working posture; and
- Determining the level of action required.

Observation and selection of the working position and posture for further assessment

Before starting the methodological procedure, an initial preparation for the assessment was done by talking to the workers being assessed in order to gain knowledge about the work operation and understand the work tasks associated with it. The assessment using the method focuses on a single moment in the work cycle [27], which was done in this research conducting observations of movements and working postures over several work cycles before selecting the posture to be assessed. The goal was to observe postures that are adopted and persist throughout the entire cycle of the work task or postures that are present for a significant period of the work cycle, as recommended [27]. The most risky and critical posture of the body, was chosen as the subject of analysis, and selected based on its duration and degree of deviation.

Assessment of the working posture

In order to achieve a higher level of efficiency, in the analysis of the working posture, according to the RULA method, the body was divided into segments that form two groups: A and B. Group A includes the upper arm and forearm together with the wrist, while group B includes the neck, trunk and legs. This division and approach ensure that the entire working posture of the body is documented, ensuring that the impact on the posture of the upper limbs of any uncomfortable or unnatural positions of the legs, trunk or neck are included in the assessment [28].

To assess the working postures according to RULA, the range of motion of the body parts was divided and appropriately labeled, with a value of 1 being assigned to the movement or working posture of the corresponding body segment where risk factors are minimally present. Higher numerical values were assigned to the parts of the range of motion that are characterized by a more extreme posture indicating an increased presence of factors that cause stress on the structure of the segment itself.

The analysis and giving values/scores of body parts from groups A and B, according to the motion ranges, for each individual worker, for the selected working posture, was entirely done according to the RULA method.

Determining the final score for the working posture

The individual scores C (score for posture A + value for muscle activity + value of the load on the parts of group A) and D (score for posture B + value for muscle activity + value of the load on the parts of group B) were entered into a table, in order to obtain the final score for the working posture of workers. The final score for the body's working posture is the value that lies at the intersection between the value/score C and the value/score D.

Determining the level of action required

In the end, the final score was compared to four action levels which indicate the level of intervention required to reduce MSDs [3] and provide an indication of the time frame within which it is reasonable to expect to start risk control [27]. The action level is used to indicate the urgency and priority of the need for a change in the way of working [7] and determines the degree of acceptability of the work attitude to the body.

4. RESULTS

The whole procedure and obtaining of scores are described in detail in this section where results are presented for each worker.

Observation, identification and selection of the working position

Before selecting the body posture for each welder individually, observations of the welders' movements and posture were conducted over several work cycles. The focus was on the postures adopted by the welders when welding joints where a significant degree of body misalignment was visually observed. Incorrect postures identified as the most risky and critical were selected for assessment. This selection was also supported by interviews with the welders, who highlighted the selected postures as the most unpleasant moments during the performance of the work task. For 4 welders, the right sides were selected for assessment, and for welder number 103, the left side of the body was selected.

The selected postures were documented by photographing them from the appropriate side (Figure 1). Additionally, photographs were taken from views parallel to the frontal plane (Figure 2) and views parallel to the position of palms (Figure 3).

Fig. 1. Selected working posture and side view of the body among welders 101 – 105

Fig. 2. View parallel to the frontal plane of the selected posture of welders 101 – 105

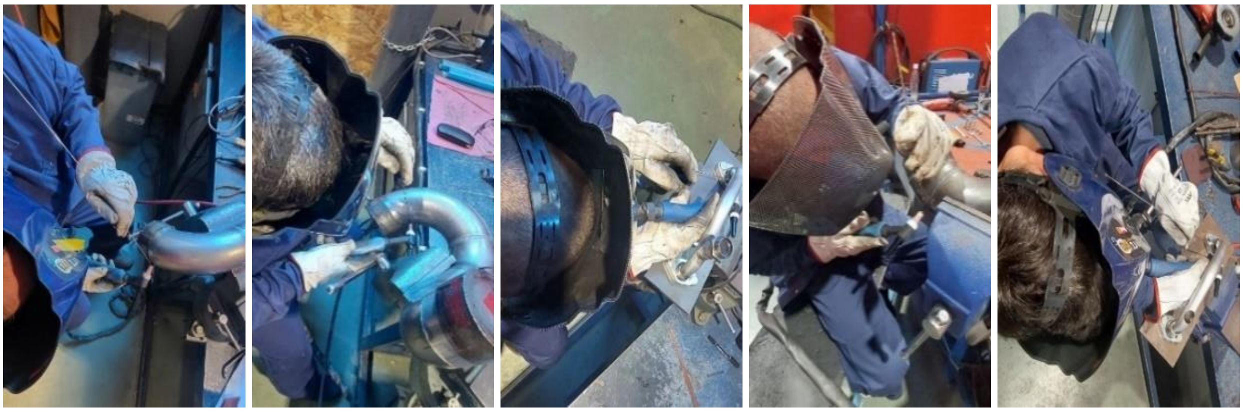

Fig. 3. View parallel to the palm placement in the selected posture of welders 101 – 105

Evaluation of the body postures and determining the acceptability

Before starting the assessment of the working posture of the body, the angles and positions of the individual parts of the body of the welders were determined. The scores were placed in appropriate tables from which scores for posture A and B were then obtained.

For example, for welder 101, the A score for the work posture is 5, and the B score is 8. The scores C and D for welder 101 are identical to the A and B scores of the working posture, accordingly, since no additional values are given for muscle activity and load value, because: the working posture of the body of the welder is not static for more than 1 minute; the working posture does not repeat more than 4 times a minute; and the load is less than 2 kg. Therefore, the final score for the assessed working posture of welder 101 is 7. This value corresponds to action level 4, indicating that the working posture is completely unacceptable, and conducting an additional research and implementing changes is needed immediately.

The same steps were repeated for welders 102, 103, 104, and 105 in order to obtain a final score for the working postures. The final score for the assessed working posture of welders 102 and 105 is 6. This value corresponds to action level 3, c that the working posture is partially acceptable, and conducting an additional research and implementing changes soon will be needed. For welders 103 and 104 the final score for the assessed working posture is 7. This value corresponds to action level 4, indicating that the working posture is completely unacceptable, and conducting an additional research and implementing changes is needed immediately.

Final results from the assessment

The results of the application of the RULA method (Table 3) indicated that welders were exposed to a probable and high risk of work-related MSDs of the upper limbs, without the presence of acceptable working postures of the welders. The questionnaire on manifested symptoms of MSDs noted that pain and discomfort were most prevalent in the neck area (60%) and the upper back (40%).

In the critical working postures that were the subject of the ergonomic research, the visually observed significant degree of misalignment of the body parts was confirmed by the high final scores that indicated the need to control risks, by initiating urgent corrective action to improve the workstations.

T a b l e 3

Welder data and final scores from the application of the RULA method

Welder	Age (years)	Height (cm)	Weight (kg)	Work experience in the company	Final RULA scores
101	49	172	120	24 years and 5 months	7
102	49	180	105	6 years and 3 months	6
103	27	173	75	4 years and 7 months	7
104	22	173	65	2 years and 8 months	7
105	23	170	61	1 year and 7 months	6

5. DISCUSSION

The results showed that even though factors such as age, height, weight, and work experience in the company are important factors that can affect the efficiency and proper conducting of the working task, they are not the top factors that affect the level of exposure to the risk of MSD in this case. The main risk factor was identified as the current design of the workplace/station, whose elements, such as chairs and work tables, are static and do not have any possibilities for adjustment and alignment with the different anthropometric characteristics of welders. This conclusion corresponds to the results of analyzed studies applying the RULA method presented in the background section, where the working conditions with the highest adaptability showed the lowest ergonomic risk and the best performance, and workstations which were not adaptable and not complying with ergonomic standards revealed high risks for development of MSDs in various body parts. Moreover, studies aimed to redesign work stations, equipment and machines, to address ergonomic issues and uncomfortable body postures, found improved ergonomic scores with the redesigned adjustable solutions, decreasing health risks of workers.

However, on the other hand, this study also concluded that the practices of welders were not in accordance with ergonomic standards, with incorrect positions of body parts being adopted during work postures that were unconsciously practiced and were not caused by external factors. Such practices among welders reveal a lack of knowledge about ergonomics and awareness of the importance of the correct working posture of the body during work and its significance on the functionality of the body and well-being in and outside the work environment. This result was also found in analyzed literature examples where urgent changes were indicated and a lack of awareness of ergonomics in the industry, especially in the welding process, where workers adopt incorrect working postures, was found.

Therefore, the reduction of the final score, i.e., the reduction of the risk of MSD occurrence, can be achieved by creating a plan with guidelines for improvements. In this plan, initially, all welders should acquire basic knowledge in the field of ergonomics, while appropriate education should be carried out in order to reduce or eliminate the adopted incorrect body postures that are not caused by external factors. The top management of the company should be familiar with the actual situation and conditions, as well as the economic aspects of the performance of the production system. The engineers in the company should provide practical suggestions for changes, which depending on the investment plan, should be designs of new or redesigns of existing elements of the welders' worklaces, but also proposals for purchasing new elements.

In general, specific changes should be aimed at providing mobility options for chairs and work tables, allowing for adjustment and compliance with the different anthropometric characteristics of each welder. In addition, a design of a device that will be placed on the floor should be provided, where the welders' legs and feet are well supported when sitting, and the body weight is evenly balanced. In order to prevent the load on the upper parts of the body, hand supports should be provided, as well as vices that can automatically rotate a pedal.

6. CONCLUSION

This research revealed the ergonomic shortcomings of the current design of workplaces/stations in a specific company in the metalworking industry in the Republic of North Macedonia, through the application of the RULA method. The results of the application of the method indicated the exposure of welders to a probable and high risk of work-related MSDs of the upper extremities, without the observed presence of acceptable working postures of the welders' body. It was concluded the main risk factor is the current design of the workplace/station whose elements, are static and do not have the possibility of adjusting to the different anthropometric characteristics of the welders. On the other hand, the welders had incorrect body positions, which were unconsciously adopted without being caused by any external factor, thereby revealing a lack of knowledge about ergonomics. Based on this, suggestions are given for reducing the risk of MSDs by creating a plan with guidelines for improvements. The plan includes: education of the workers and management in the company to acquire basic knowledge in the field of ergonomics, providing practical suggestions for changes aimed at ensuring the adaptability of the work equipment, and design of additional working-aid devices.

In general, the initially established finding that there is limited application of ergonomic research in companies from the manufacturing industry in North Macedonia was confirmed. As expected, this study revealed issues which were not resolved previously in the specific company since no deeper analysis of the individuals work stations was done. However, this research confirmed that the RULA method is easy to apply. It provides a good indication of the degree of acceptability and the action levels that should be taken. The conducted research contributed to drawing conclusions that the middle and senior management in the company should take in order to improve working conditions and eliminate risks. All participants in the study gained knowledge and awareness of the importance of proper body posture and its impact on body function and well-being in and outside the work environment.

The limitation of this ergonomic study was that it did not include detailed information on finger position, which is a major limitation in the assessent of the welder's overall risk. However, since the observed risk factors are still high even without such inclusion, the relevance of finger position is considered, and it is proposed to fill the gaps by using other assessment tools as part of future, broader or more detailed ergonomic research.

The following step of this research is to optimize the working stations of the welders according to the proposed solutions and obtain the new RULA scores which will indicate if there is a significant connection between the specific redesigns and the welders working body postures. This process can then be finalized by proposing an ergonomic evaluation framework which can be easily applied in other companies from the industry, involving larger study groups, and covering more working operations. Such framework can provide significant data which will encourage the application of ergonomic studies in North Macedonia for reducing health risks in working systems.

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