p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 5, No. 9 September 2024 http://jist.publikasiindonesia.id/

Designing Welding Workstations to Reduce the Risk of MSDS (Musculoskeletal Disorders)

Machdian Muharam[1*], Maya Arlini puspasari[2]
Universitas Indonesia, Indonesia
Email: ian.muharam21@gmail.com

*Correspondence

Keywords: ergonomics, workstation welding, musculoskeletal disorders, rule.

ABSTRACT

This study aims to design an ergonomic welding workstation to reduce the risk of Musculoskeletal Disorders (MSDs) in welding workers at PT. Sinar Bharata Perkasa. The background of this study is the high prevalence of MSDs in welding workers due to unergonomic work posture. The methods used include posture analysis using Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA), as well as anthropometric calculations to design workstations that suit the physical condition of workers. Data collection was carried out through the Nordic Body Map (NBM) questionnaire and posture measurements before and after the design improvement. The results showed that the new workstation design was able to significantly reduce the risk of MSDs, with a decrease in the RULA score from 6 to 3 and the REBA score from 8 to 3. In conclusion, this new workstation design has the potential to improve the health and productivity of welding workers at PT. Sinar Bharata Perkasa.

Introduction

Welding is a way to connect two pieces of metal or more, both ferrous and non-ferrous, with the process of melting the parent metal and/or filler metal to produce a continuous connection with or without the use of pressure (Yuslistyari & Adhadin, 2018), In welding operations, the physical dimensions of the workstation have a significant influence from the point of view of production efficiency and the physical and mental well-being of the operator (Anthony, 2020). Physical dimensions in industrial workstation design are essential for the perspective of production efficiency and occupational health and safety (Urgiles et al., 2019). (Mahir, 2023) stated several factors that need to be considered when analyzing and designing a welding environment including the physical abilities of the workers, the weight of the welding gun, the design tools, the mechanics of the body during welding, the type of protective equipment used, the workspace, and the physical requirements of the job and the job position. This type of work that involves the physical and is carried out in inappropriate ways, let alone repeatedly, can slowly cause musculoskeletal disorders. This needs to be taken seriously, as it can lead to more severe consequences. Since there is a strong association between other occupational risk factors and work posture, there is a need to assess how they intend to increase productivity (Thoriq & Sutejo, 2017). The prevalence of MSD disorders according to the World Health Organization (WHO) reaches around 60% of all occupational diseases (Saraswati, 2020). Meanwhile, data from the Labour Force Survey (LFS) in 2017 shows that Musculoskeletal Disorders (MSDs) in the last 3 years are ranked second out of all cases of occupational accidents and diseases reaching 469,000 cases (prevalence of 34.54%) (Mulyadi & Iswanto, 2020). In Indonesia, data on MSDs statistically with details are not yet available. However, based on Riskesdas data in 2018, there were 9.2% of injuries resulted in disruption of daily activities in Indonesia, and 9.1% occurred in the workplace environment. The tendency of joint diseases in the population or workforce over 15 years old in Indonesia is around 7.3%. However, data (figure 1) from BPJS Kesehatan shows that the cost of health services sourced from occupational diseases shows a fairly high intensity every year. This shows that it is quite serious for the handling of prevention (Shufiyah, 2018).

There have been previous studies that have reviewed the design of workstations for welding areas. The process of designing this workstation involves the application of the DFMA or Design for Manufacture and Assembly method and the assembly method selection diagram. (Dahda & Rizqi, 2022). The result of the workstation design includes a workbench equipped with a footrest to make it easier for the operator to rest, a place for a protractor, a welding wire container, a workpiece base plane, and an area for placing the material to be welded. There are also clamps in the form of a vise with a height of 73 cm, a length of 60 cm, and a width of 60 cm. (Anwardi et al., 2019), while Hilman (Fauzi & Khusuma, 2020) Made a design for this ergonomic workstation including a table with a height of 112 cm, a length of 200 cm, and a width of 75 cm, this was developed to reduce muscle fatigue and discomfort in the workplace and the height of the table is 5-10 cm above the height of the worker's elbow when standing.

Many studies have studied the design of workstations in the welding area. Some focus on risk analysis and posture evaluation. The object of the research is a welding area workstation in a company in the city of Bekasi, West Java.

However, comprehensive research that integrates all aspects, including posture analysis, anthropometry, productivity, cost, design visualization, layout, and welding workstations is still limited. Most previous studies have only evaluated postures or proposed designs without an approach that considers all relevant factors. In addition, posture evaluation before and after design improvements using the Nigel Cross model has not been explored in depth for welding workstations. Therefore, the researcher conducted research that can be a novelty value, namely by designing a welding workstation that will be implemented at PT. Sinar Bharata Perkasa. The results of the research are in the form of design and visualization which will be designed based on posture analysis of existing work activities. The existing design will be designed using the Nigel Cross model whose data is primary data in the field. Posture evaluation is carried out before and after design improvements to evaluate the design results until the final design is produced.

Method

Research Subjects and Data Collection

The subject of the study is a welding operator whose anthropometric data is secondary data taken from Indonesia's anthropometry. Org (2018) (www.antropometriindonesia.org). The anthropometric data used in this study are 36 anthropometric dimensions which are measurements, for all ethnicities, males, and measurement times from 2000 – 2018 with an age range of 17 to 47.

From the existing data, calculations will be carried out by calculating percentiles for existing dimensions, using the formula (2-1), and the combined standard deviation will be calculated using the formula (2-2).

This study adapts following the steps used in the rationality model from Nigel Cross which includes 7 steps of clarification Objective, Establishing Function, Setting Requirement, Determining Characteristic, General Alternative, Evaluation Alternative,

N1M1+N2M2 N1+ N2 (2-1)

Improving Detail Engineering Design Methods Strategies for Product Design (Nigel Cross, 2000).

RULA and REBA Measurement

RULA is an approach to evaluate the ergonomics of workers' posture, focusing on the upper body. RULA analysis is used when there are complaints related to discomfort in the upper body due to unergonomic work posture (McAtamney and Corlett, 1993). The advantage of this method lies in its ease of use as it does not require special equipment. Factors to consider in the analysis include the position of the body when in a static state when working, load, duration, and use of muscle energy in working.

REBA is a systematic method used to evaluate the body position of all workers to identify the risk of Musculoskeletal Disorders (MSDs) and other related occupational risks (Ergonomics Plus, n, d.). REBA was first introduced by Hignett and McAtamney (Hignett et al, 2000). A REBA sheet is used to assess energy use, posture, type of movement, coupling, and repetition. REBA was developed to be easy to use without the need for high skills or expensive equipment. In its use, REBA only requires REBA sheets and stationery.

From the results of RULA and REBA, a value with a risk level for MSDs was obtained.

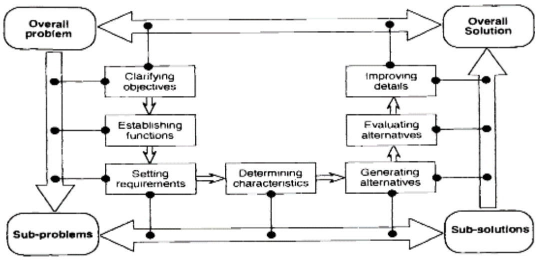


Figure 1. Research flow

The research flow adapted from these 7 steps is only limited to the Evaluation alternatives phase, that is, the seventh phase, namely Improving details is not carried out in this study. The reason this research only adapts the initial 6 phases is because this research is only limited to the stage of producing improvement designs, not considering the production process and the release process to the market.

1) Clarifying Objective

The first phase begins with a preliminary study, exploring the basic information of potential subjects, compiling the background of why this research is conducted, formulating problems obtained from information in the field, determining the limitations in conducting this research, and preparing a research plan, starting from how this research will be conducted, what data is needed, how the stages of the research process are carried out until the final output.

The steps are as follows:

a. Compile a list of design goals by summarizing information based on questions to users, design reports, and design team discussions.
b. Preparation of a list of goals from higher level to lower level. From this process comes a list of goals and sub-objectives that are roughly grouped into hierarchical levels.
c. Compile a goal tree diagram, as a visualization of existing relationships.

2) Penetapan Fungsi (Establishing Function)

This stage has the purpose of identifying the functions that occur in a design. This step involves drawing system constraints that include the functions and sub-sub-functions of the planned tool, transparent box, and black box.

3) Setting Requirements

Compile a table that contains details of the specifications of the tool based on the data obtained from the questionnaire. The detailed table of specifications includes the requirements that need to be met (demand) and things expected (wishes) by respondents.

4) Determining Characteristic

The determination of product characteristics aims to identify the targets to be achieved through the technical characteristics of a product, to meet the needs of respondents. The opinions of other stakeholders were determined, and respondents were given a questionnaire about several alternative options.

5) Evaluating alternatives

In this stage, a questionnaire containing several alternative designs of the new tool was distributed to respondents. Respondents were asked to choose one of several options provided to identify one alternative option. The chosen alternative will be the basis for designing a new welding workstation.

6) Communication (improving details)

The components of the new device are described in detail, to make modifications to add value without adding or reducing costs and still maintaining the existing value. Market surveys are conducted to find out the price of each component. After knowing the price of the components, an evaluation is carried out on the modification of the device. However, cost calculations were not included in this study.

Statistical Calculation of Questionnaire Data

This study uses 2 types of questionnaire calculations statistically as follows:

a. Validity Test

Validity testing was carried out to evaluate the accuracy of the data collection instruments that had been used by utilizing data from closed questionnaires. It can be seen in equations 2-3.

b. Reliability Test

In this stage, alternatives are determined by compiling a morphological chart that includes functions and ways of achieving them. These alternatives are based on the results of a questionnaire given to respondents and interviews with experts. Based on alternatives.

Reliability testing is carried out after the data is confirmed as valid data to evaluate the measurement results. Reliability testing uses the same software as the validity test, namely SPSS software. It can be seen in equations 2-4.

Results and Discussion

Literature Studies and Design

Literature studies are carried out on previous studies. A literature study was conducted for the selection of anthropometric dimensions and appropriate designs for use in determining dimensions for tables and chairs in welding workstations.

Based on the activities carried out by workers at PT. X will be calculated RULA (Rapid Upper Limp Assessment) and REBA (Rapid Entire Body Assessment) from the measurements shown below.

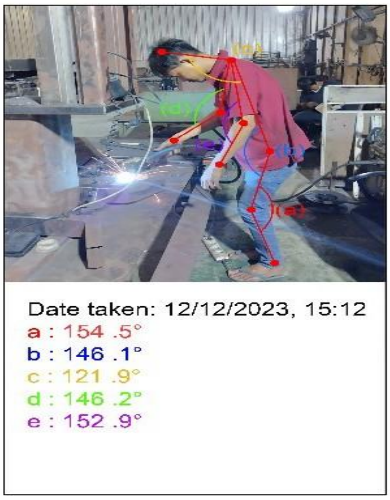


Figure 2 Worker standing position

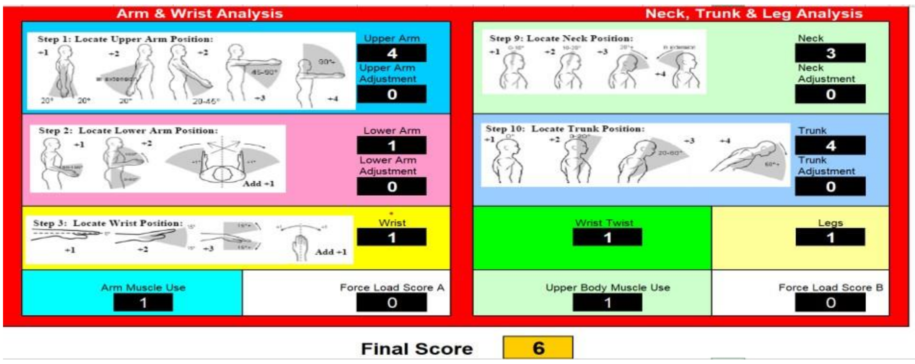


Figure 3 Worker RULA standing

While REBA is as follows:

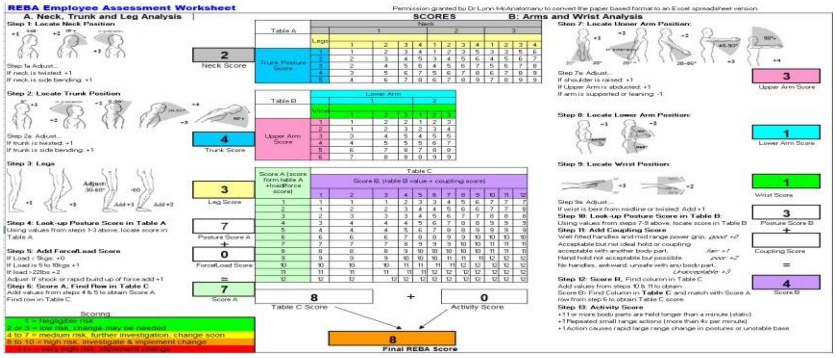


Figure 4 REBA worker standing position

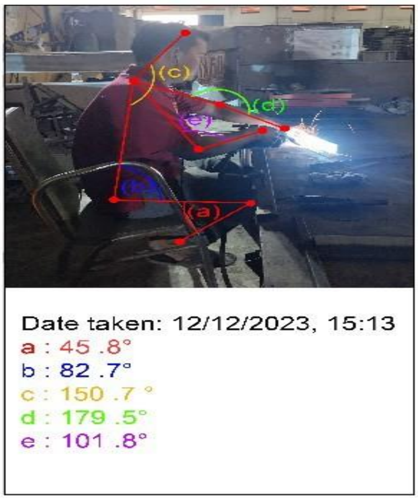


Figure 5 Worker sitting position

While RULA with a sitting position:

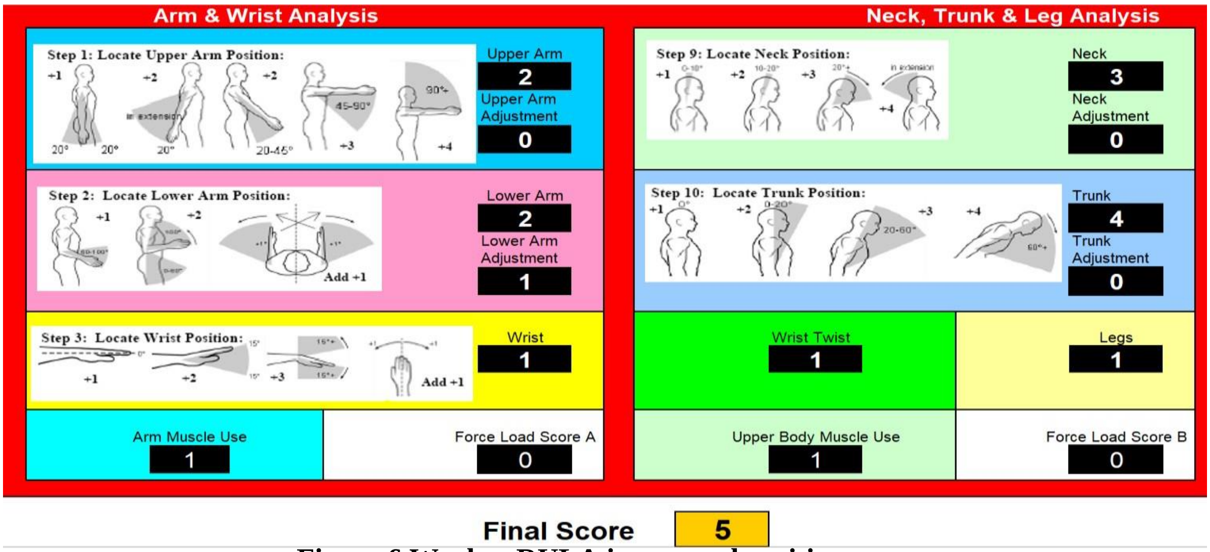


Figure 6 Worker RULA in a seated position

As for REBA with a sitting position:

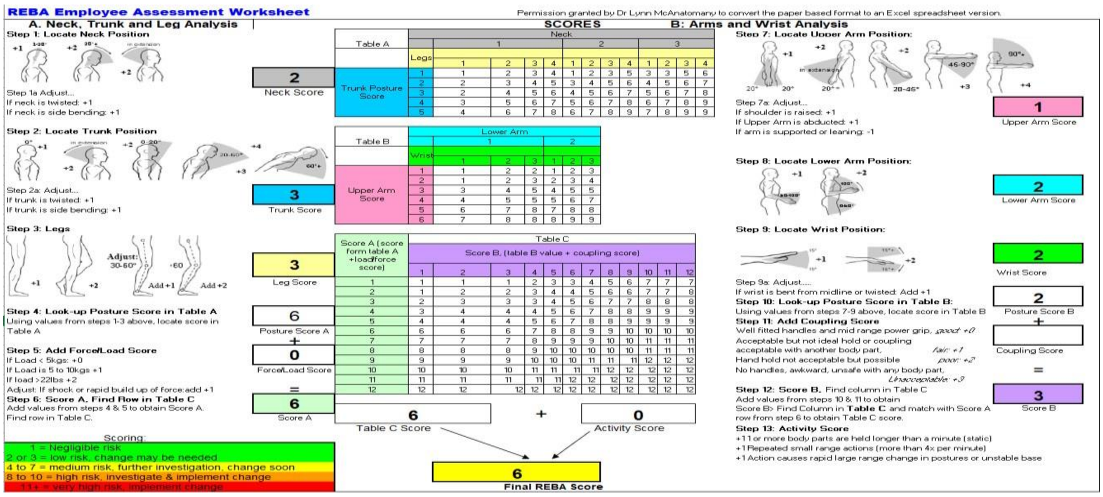
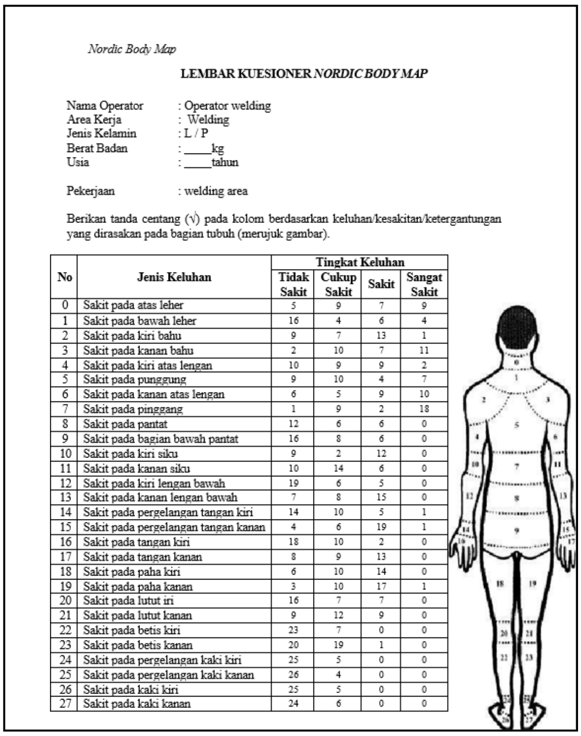


Figure 7 REBA worker in a seated position

From the data above, it turns out that the RULA and REBA values for the condition of workers without desks are 6 and 8, so with these values, the condition of workers has a high enough risk to be affected by MSDs and it is necessary to investigate and implement improvements as soon as possible. As for workers using the value table Kuesioner Nordic Body Map (NBM).

RULA and REBA range from 5 and 6 which means that workers using existing tables are still exposed to the risk of MSDs even though the risk is medium, so it is necessary to reduce the above values by improving the design to further reduce the risk of MSDS for workers in the welding area.

In identifying the complaints experienced by operators, the researcher conducted a questionnaire using the Nordic Body Map (NBM), from the results of the questionnaire the following data was obtained:



Nordic Body Map

LEMBAR KUESIONER *NORDIC BODY MAP*

Nama Operator : Operator welding
Area Kerja : Welding
Jenis Kelamin : L / P
Berat Badan : _____kg
Usia : _____tahun

Pekerjaan : welding area

Berikan tanda centang (√) pada kolom berdasarkan keluhan/kesakitan/ketergantungan yang dirasakan pada bagian tubuh (merujuk gambar).

No	Jenis Keluhan	Tingkat Keluhan			
		Tidak Sakit	Cukup Sakit	Sakit	Sangat Sakit
0	Sakit pada atas leher	5	9	7	9
1	Sakit pada bawah leher	16	4	6	4
2	Sakit pada kiri bahu	9	7	13	1
3	Sakit pada kanan bahu	2	10	7	11
4	Sakit pada kiri atas lengan	10	9	9	2
5	Sakit pada punggung	9	10	4	7
6	Sakit pada kanan atas lengan	6	5	9	10
7	Sakit pada pinggang	1	9	2	18
8	Sakit pada pantat	12	6	6	0
9	Sakit pada bagian bawah pantat	16	8	6	0
10	Sakit pada kiri siku	9	2	12	0
11	Sakit pada kanan siku	10	14	6	0
12	Sakit pada kiri lengan bawah	19	6	5	0
13	Sakit pada kanan lengan bawah	7	8	15	0
14	Sakit pada pergelangan tangan kiri	14	10	5	1
15	Sakit pada pergelangan tangan kanan	4	6	19	1
16	Sakit pada tangan kiri	18	10	2	0
17	Sakit pada tangan kanan	8	9	13	0
18	Sakit pada paha kiri	6	10	14	0
19	Sakit pada paha kanan	3	10	17	1
20	Sakit pada lutut iri	16	7	7	0
21	Sakit pada lutut kanan	9	12	9	0
22	Sakit pada betis kiri	23	7	0	0
23	Sakit pada betis kanan	20	19	1	0
24	Sakit pada pergelangan kaki kiri	25	5	0	0
25	Sakit pada pergelangan kaki kanan	26	4	0	0
26	Sakit pada kaki kiri	25	5	0	0
27	Sakit pada kaki kanan	24	6	0	0

Figure 8 Nordic Body Map Questionnaire (NBM)

From the data obtained, weighting was carried out with a Linkert scale from scale 1 to 4, namely so that data on pain in the right shoulder, right upper arm, and waist dominated the workers' complaints.

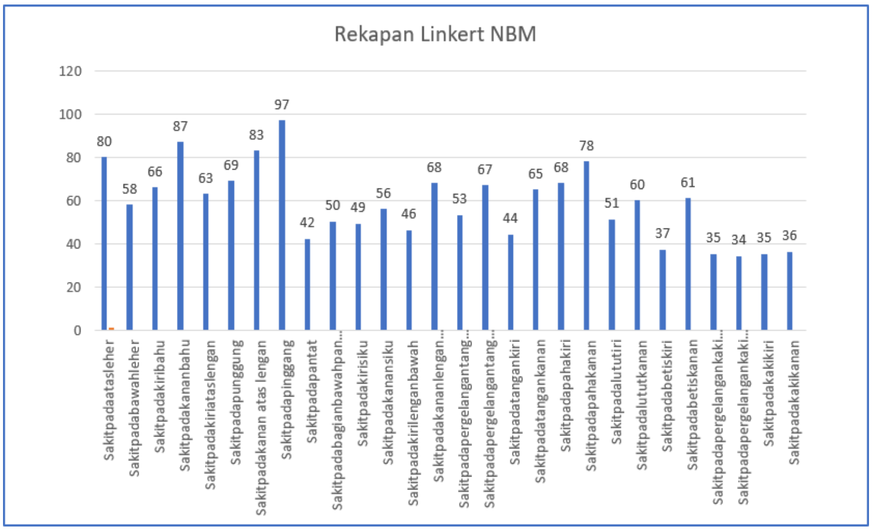


Figure 9 Recap of the Nordic Body Map (NBM) Questionnaire

Anthropometric Calculations

Calculations of 5th, 50th, and 95th percentile values are carried out for each dimension based on the average value and standard deviation. The calculation of percentile values is carried out by adding the average value with the result of multiplication between the standard deviation and the multiplier factor according to the required percentile. In this study, the multiplier factor used was -1.645 for the calculation of the 5th percentile, the multiplier factor of 0 for the 50th percentile, and the multiplier factor of 1.645 for the calculation of the 95th percentile. For example, for the height dimension of the body, the average value is 148.18 cm with a standard deviation of 1.9 cm, then the calculation of the percentile is 5, 50, and 95:

$\boldsymbol{Nilai\ Persentil\ 5\ (D1)} = Mean - 1{,}645 \times Stdev$
$= 148{,}18 - 1{,}645 \times 15{,}66$
$= 122{,}42$
$\boldsymbol{Nilai\ Persentil\ 50\ (D1)} = Mean + 0 \times Stdev$
$= 148{,}18 + 0 \times 15{,}66$
$= 148{,}18$
$\boldsymbol{Nilai\ Persentil\ 95\ (D1)} = Mean + 1{,}645 \times Stdev$
$= 148{,}18 + 1{,}645 \times 15{,}66$
$= 173{,}94$

Thus, it was found that the magnitude of the 5th percentile value for the height dimension of the body (D1) was 122.42 cm, the 50th percentile was 14.18 cm and the 95th percentile was 173.94 cm. The results of the calculation of percentile values for each dimension are illustrated in Table 1.

Table 1
5thrants, 50, and 95 Percentile Values Each

D14	36,27	45,80	55,33
D15	42,28	52,42	62,56
D16	33,02	42,00	50,97
D17	27,67	40,91	54,15
D18	22,14	33,14	44,15
D19	30,48	43,45	56,43
D20	11,14	22,89	34,64
D21	12,63	28,34	44,06
D22	21,91	29,81	37,71
D23	27,83	38,60	49,36
D24	55,32	66,48	77,64
D25	39,82	49,69	59,57
D26	12,61	18,11	23,61
D27	13,60	20,50	27,40
D28	10,97	17,41	23,85
D29	6,77	10,55	14,33
D30	16,87	22,64	28,41
D31	7,61	10,84	14,08
D32	116,76	144,00	171,23

D33	59,81	72,80	85,79
D34	145,20	188,23	231,27
D35	87,79	123,14	158,50

Validity and Reliability Test

1. Validity Test (moved up)

From the 30 available data to assess the level of desire of respondents for welding workstations. Validity tests were conducted to evaluate the extent to which the questions presented in the questionnaire could reflect the overall behavior of the respondents. The results of the Validity Test were carried out using SPSS for r table 5% for N =30 and the results are as shown in table 2.

Table 2
Validity Test Scores

No. Grain	r Calculate	r Table	Information
1	0,844	0,361	Valid
2	0,427	0,361	Valid
3	0,846	0,361	Valid
4	0,685	0,361	Valid
5	0,376	0,361	Valid
6	0,844	0,361	Valid
7	0,437	0,361	Valid
8	0,677	0,361	Valid
9	0,824	0,361	Valid

2. Reliability Test

For the existing data, a reliability test is carried out to determine the uniformity of the data, by calculating the value of Alpha Cronbach. The results of this test can be seen in Table 8 below, from the existing data, the value of r Calculate is greater than r Table so it can be concluded that the existing data is reliable.

Table 3
Reliability Test Score

Attribute	r Calculate	r Table	Information
Cronbac	0,832	0,361	*Reliable*

h's *Alpha*

Nigel Cross design model

The design guidelines of the welding workstation are made based on the anthropometric considerations of the operator as the user and the improvement effect of the design before and after it is carried out. In the preparation of this design, it is carried out by reference following the 7 steps in the design model, the results of these steps are as follows:

3. Clarifying Objective

Creating a goal setting by creating an objection tree which is the result of digging for input/ideas from users, can be described as follows:

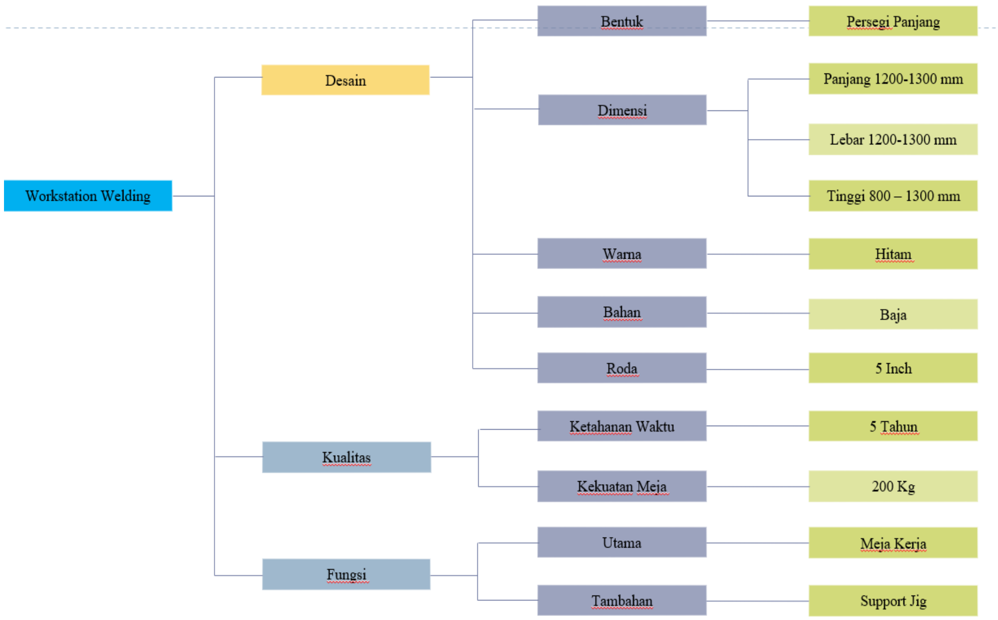


Figure 10. Destination Tree

a. Establishing Function creates a black box that aims to determine the process that will be carried out to determine that thewelding workstation can be implemented into a product. For the black box which is described as a process flow for the manufacture of welding workstations.
b. Preparing Requirements (setting requirements) Contains a table that is the need for a product to be designed, this table contains requirements that are by the wishes (D) and expectations (W) of users from welding workstations based on questionnaires at PT. Sinar Bharata Perkasa.

Table 4
Setting requirement

D or W	Condition
W	Square table

W	Dimensions: 2000 x 1200 x 500-600 mm
W	Black table
W	Table with Steel material
D	Table with 5-inch wheels
D	Has a durability of 5 years
W	Table Power up to 200 Kg
W	Main functions of the workbench
W	Functional table support jig

c. Determining Characteristic

In this step, QFD (Quality Function Deployment) is prepared, the goal is to find characteristics to suit customer requests by prioritizing the design quality of the product compared to existing competitors so that the product can be made based on requests from users/users. The existing characteristics are expected to be able to adjust their desires by exploring the expectations of users.

d. Determining alternatives

At this stage, a morphological chart was developed to see the alternatives to welding workstations as follows.

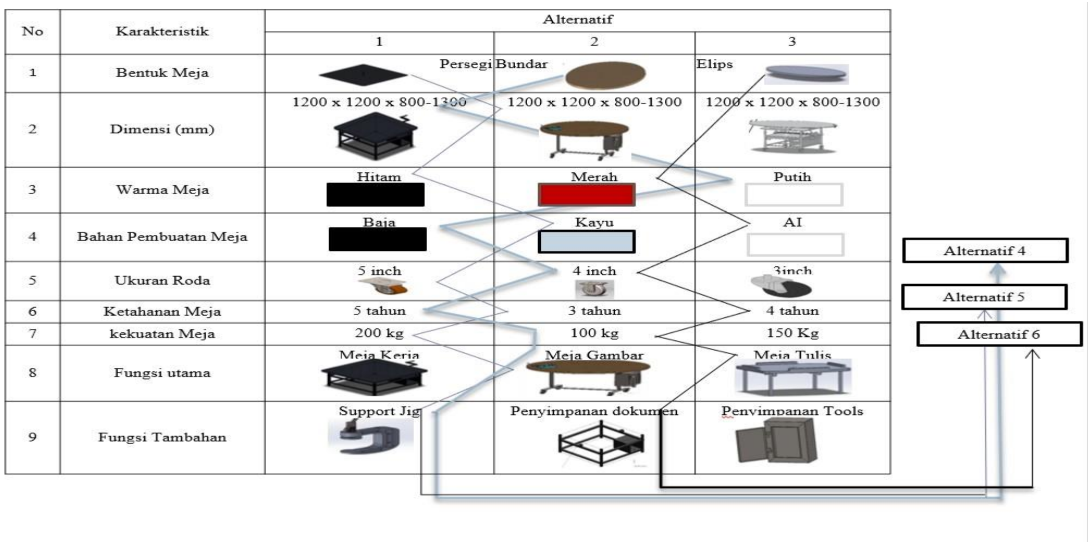


Figure 11 Morphological chart

Table 5
Attribute Weighting Table

Value scale	Function	Description of sub-functions	In
10	D	Table/tool height	10/52=19,23%

9	A	Table size	9/52=17,31%
8	G	Using the wheel	8/52=15,38%
7	C	Tool power	7/52=13,46%
6	B	Frame Material	6/52=11,54%
5	And	Swivel table	5/52=9,62%
4	H	Storage Rack	4/52=7,69%
3	F	Heat sucker	3/52=5,77%
2	-	-	
1	-		

From the existing morphological chart, there are 3 alternatives with 9 attributes so from the data above there are 39 alternatives, totaling 19,683 alternatives which will then be carried out in the alternative evaluation stage by looking at the weighting of existing attributes to others, for this a questionnaire will be carried out to see the response from users to the existing alternatives.

e. In this phase, several welding workstation design alternatives that have been produced will be evaluated, and one of the two best options will be selected, this selection aims to ensure that the workstation design can produce the best product among the several alternatives available. So that the design for the welding workstation table is carried out based on the existing anthropometric needs, and at this stage, a simulation will also be carried out using Siemens Jack software to see the posture analysis of the existing design.

f. Communication (improving details)

At this stage, design is carried out by choosing alternatives that have been determined, taking into account anthropometric factors that have been taken into account beforehand. In addition, the next value engineering will also be considered for the design of the resulting product.

In value engineering, all the parts and components needed will be listed so that the value of the product produced can be calculated.

Conclusion

This study aims to design an ergonomic welding workstation to reduce the risk of musculoskeletal disorders (MSDs) in welding workers at PT. Sinar Bharata Perkasa. The calculation of RULA and REBA scores shows that the current working conditions have a fairly high risk of MSDs for workers, both when working without a desk and with existing desk conditions. The Nordic Body Map questionnaire revealed that the main complaints of workers were in the right shoulder area, right upper arm, and waist. The design of the new welding workstation table is carried out by considering the anthropometric data of the worker, including the dimensions of body height, sitting shoulder height, upper arm length, and so on. In addition, the purpose, functions, needs, and characteristics of the workstation are also determined based on input from users through questionnaires. Alternative workstation designs are generated with morphological charts and an evaluation process using Quality Function Deployment (QFD). The selected alternatives were then designed in detail taking into account ergonomic factors and simulated working postures using Siemens Jack software. Before the design of the RULA value in the standing and sitting positions was 6 and 5, and for REBA it was 8 and 6, after the design of the RULA value obtained from the simulation results with the jack software, there was an improvement in the standing and sitting position with a value of 3 so that the design of the existing workstation table could reduce the risk of MSDs (Musculoskeletal Disorder) of welding workers at PT. Sinar Bharata Perkasa.

The theoretical implications of this study are in the form of new contributions to the application of ergonomic principles in the design of workstations in the manufacturing industry, especially for welding work. The study combines various analytical methods such as RULA, REBA, anthropometry, QFD, and simulation in one systematic product design framework. The findings of the study can enrich the literature related to the design of welding workstations that are safe and comfortable for workers.

The practical implications of the new workstation design research resulting from this research have the potential to be applied in PT. Sinar Bharata Perkasa to reduce the risk of MSDs to welding workers. This design can also be adapted for use in other companies that have similar welding activities. This research has several limitations. The research was only conducted at PT. Sinar Bharata Perkasa with a limited sample number of workers. In addition, similar studies need to be conducted on other industries taking into account specific factors such as the type of work, environmental conditions, and worker characteristics to obtain a broader generalization. Future research may explore other MSD mitigation efforts such as job rotation, posture training, and management interventions.

Bibliography

Anthony, M. B. (2020). Analisis postur pekerja pengelasan di CV. XYZ dengan metode Rapid Entire Body Assessment (REBA). *Jurnal Jati Unik*, *3*(2), 110–119.

Anwardi, M. I., Nofirza, H., & Ahmad, M. (2019). Perancangan Alat Bantu Memanen Karet Ergonomis Guna Mengurangi Resiko Musculoskeletal Disorder Menggunakan Metode RULA dan EFD. *J. Tek. Ind*, *5*(2).

Dahda, S. S., & Rizqi, A. W. (2022). Analisis Postur Tubuh Pekerja Pada Stasiun Kerja Pemotongan Pipa Untuk Mengurangi Musculoskeletal Disorder (Msds). *JUSTI (Jurnal Sistem Dan Teknik Industri)*, *3*(1), 95–105.

Fauzi, I., & Khusuma, I. H. S. (2020). Teachers' elementary school in online learning of COVID-19 pandemic conditions. *Jurnal Iqra': Kajian Ilmu Pendidikan*, *5*(1), 58–70.

Mahir, I. (2023). *Keselamatan Kerja Bengkel Otomotif (Edisi Revisi)*. Bumi Aksara.

Mulyadi, S. T., & Iswanto, I. (2020). *Teknologi Pengelasan*. UMSIDA Press.

Saraswati, L. A. (2020). Cosmopolitan whiteness: The effects and effects of skin-whitening advertisements in a transnational women's magazine in Indonesia. *Meridians*, *19*(S1), 363–388.

Shufiyah, S. B. (2018). *Analisis Risiko Musculoskeletal Disorders (MSDs) Pada Pekerja Las Titik Dengan Metode Quick Exposure Checklist (QEC)*. Universitas Brawijaya.

Thoriq, A., & Sutejo, A. (2017). Desain dan uji kinerja mesin pemarut sagu tipe TPB 01. *Agritech*, *37*(4), 453–461.

Urgiles, V. L., Székely, P., Székely, D., Christodoulides, N., Sanchez-Nivicela, J. C., & Savage, A. E. (2019). Genetic delimitation of Pristimantisorestes (Lynch, 1979) and P. saturninoi Brito et al., 2017 and description of two new terrestrial frogs from the Pristimantisorestes species group (Anura, Strabomantidae). *ZooKeys*, *864*, 111.

Yuslistyari, E. I., & Adhadin, A. (2018). Perbaikan Postur Kerja Operator Pengelasan dengan Metode Quick Exposure Check (QEC). *Jurnal INTECH Teknik Industri Universitas Serang Raya*, *4*(1), 17–22.