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APPLICATION OF ANTHROPOMETRIC DATA ON REDESIGN OF LIGHTWEIGHT BRICK-CUTTING TOOLS TO REDUCE WORKERS' MUSCULOSKELETAL COMPLAINTS

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Abstract. The work of cutting lightweight bricks manually with the help of cutting tools still leaves problems. Unnatural working postures are a form of problems faced by workers. This causes musculoskeletal complaints that have an impact on comfort at work. To overcome this, a redesign of the lightweight brick-cutting tool was carried out using worker anthropometric data. The redesign was carried out on the pedal switch and work chair because this caused complaints from workers. The results of the redesign reduced the musculoskeletal complaints of workers who did lightweight brick-cutting work by an average of 49.36%. This figure was obtained from measurements after working on the old and new tools. The decrease occurred from an average of 62.8 when using the old tool to 31.8 after the intervention. The study results can be used as a guideline for workers doing manual work to create a comfortable and sustainable working atmosphere.

Keywords : Anthropometry, Musculoskeletal complaints, Redesign, Ergonomics.

1. INTRODUCTION

Musculoskeletal complaints are often experienced by workers who work manually. This is the impact of unnatural work postures due to the lack of compatibility between workers and their work and the work tools used. Unnatural and unusual work postures cause musculoskeletal complaints, and exposure increases the risk of work injuries [1, 2]. Applying anthropometric data to manual work, such as in lightweight brick-cutting workers, can produce a natural work posture. Existing work tools are redesigned with data on the body dimensions of workers as users to reduce the occurrence of musculoskeletal complaints. This is part of ergonomic measures to prevent sources of disease through engineering.

By redesigning work tools based on workers' anthropometric data, engineering is needed as an ergonomic intervention step so that work postures become more natural. The decrease in musculoskeletal disorders (MSDs) is currently widely the impact of ergonomic interventions [3]. Complaints in the musculoskeletal system are complaints in the skeletal muscle felt by a person, ranging from very mild to very painful. Complaints that result in permanent injuries are usually called musculoskeletal disorders (MSDs) or injuries to the musculoskeletal system. Creating an effective, comfortable, safe, healthy, and efficient work atmosphere resulted from anthropometric data in creating a match between users and the tools used [4]. Anthropometric data is measured based on measurements of important body dimension parts according to the work tool to be designed. This is to determine the workers' interaction with their work equipment so that it is ergonomic and in accordance with the workers' body dimensions. Decreased levels of pain, risk of work posture, and increased productivity as a result of improvements in workstations [5]. Musculoskeletal disorders during manual handling, such as activities that produce vibrations, lifting, lowering, pushing, and pulling, indicate that workers have high ergonomic issues that can be helped through ergonomic equipment categorization to select specific task risk analysis and posture analysis [6]. Manual work carried out by workers using tools that are not to the worker's posture is common. Some factors that cause musculoskeletal complaints include excessive muscle stretching, for example, pushing or pulling; repetitive activities, for example, hoeing; unnatural work postures, for example, squatting, bending, out of reach; and combinations, for example, working under exposure to the hot sun. This is due to workers' low knowledge regarding ergonomic work postures, experience, and carelessness. In addition, workers pay less attention to the comfort and sustainability of the work being done. The production process carried out manually or manual handling, if done incorrectly, causes disorders of the nervous system, tendons, bones, and muscles, which are referred to as musculoskeletal disorders [7]. Manual material handling that occurs in small and medium industries causes musculoskeletal disorders experienced by workers [8]. Lower and upper back pain, hands, shoulders, neck, wrists, ankles, knees, and elbows as symptoms of musculoskeletal disorders and can be reduced by training workers in ergonomics and alternating work postures [9, 10]. Work, as shown in Figure 1, is classified as manual with the help of work tools that are not yet ergonomic. This can be seen from the worker's less natural posture, especially in the feet and hands, which affects the sitting position.

Figure 1. Workers and lightweight brick-cutting tools

Based on Figure 1, the pedal switch is located quite far from the reach of the feet, so workers experience complaints such as sore left legs after working. In addition, the sitting work position causes complaints in the waist because the seat used is not by the worker's working posture. Based on preliminary data collection using the Nordic Body Maps (NBM) questionnaire, the average level of musculoskeletal complaints was found to be above 60 points. According to Tarwaka [11], a score of 50-70 is in the moderate risk category, and corrective action is needed. Repairs were made to work tools that caused musculoskeletal complaints to workers. Measurement of the level of musculoskeletal complaints is part of the application of ergonomic principles. A production process like this requires ergonomic handling to reduce complaints due to unnatural working postures. The ergonomic approach, through the application of anthropometric data on rice threshing machines, can reduce operator musculoskeletal complaints from 60 to 12 [12]. The application of ergonomics with worker anthropometric data in the design of work tools for small farmers, such as mangosteen harvesters, solar hybrid dryers, drying chambers, and metal liquid pouring tools, can reduce musculoskeletal complaints and increase productivity [13, 14, 15, 16]. Redesigning work tools is needed through collaboration between the ergonomics and mechanical engineering fields, which is called ergo-mechanical. Work problems related to work tools, ergonomics, and occupational health and safety can be overcome by implementing ergo-mechanical [17]. Modifying work equipment with ergonomic interventions in the production process has an impact on reducing unnecessary movements, physical demands, workers' compensation costs, and injury rates [18]. The application of Ergo-mechanical to redesign or design work tools is a system of implementing integrated ergonomic and mechanical principles to create ergonomic work tools, namely technical standards such as service requirements, products, and materials, as well as comfortable use by workers [19]. In the study, work tools and seats were redesigned according to the posture of workers cutting lightweight bricks. Redesign based on input from workers to create comfortable, safe work and easy-to-operate work tools.

2. METHODS

The study used tools and materials such as lightweight brick cutting tools, lightweight bricks, workers as samples, Nordic body maps questionnaires, anthropometers or meters, anthropometric tables, and percentile tables. It was conducted through a case study in one of the industries that produces lightweight bricks in Batunyala, Central

Praya, Central Lombok Regency-Lombok. The application of anthropometry is measuring the dimensions of the worker's body according to the needs of the redesigned work tools and worker seats.

The worker anthropometric data was measured for a sitting position because the work was done with a sitting posture. In this study, a redesign of the lightweight brick-cutting tool was carried out, especially on the pedal switching, worker seat, and the addition of a footrest. The location of the pedal switching, as in Figure 1, is far from the reach of the worker's feet, causing complaints such as pain in the left leg. The pedal switching was redesigned by changing the position and dimensions. A footrest was added to support the workers' feet so they would not fall into the existing channel. The worker's seat was redesigned by changing the dimensions and adding armrests and foam. Worker anthropometric data was used in redesigning the work tool by measuring important or needed body dimensions in the redesign, determining the user population, in this case, workers who cut lightweight bricks, calculating percentile values, and applications in the redesign of the tool. Anthropometric data and percentile values used include popliteal height and 5th and 95th percentile values; popliteal buttock distance with 50th percentile value; shoulder width with 50th percentile value; hip width with 95th percentile value; shoulder height with 50th percentile value; elbow height with 5th and 95th percentile values; arm width with 95th percentile value; arm length with 50th percentile value; foot length using 95th percentile value; foot width using 50th percentile value. The number of samples based on workers working in the lightweight brick-cutting section is 5 men. The calculation of the 5th, 50th, and 95th percentile values is as presented in Equations 1-3 sequentially.

$$\text{Percentile } 5 = \bar{x} - (1{,}65 \text{ x SD}) \quad (1)$$

$$\text{Percentile } 50 = \bar{x} \quad (2)$$

$$\text{Percentile } 95 = \bar{x} + (1{,}65 \text{ x SD}) \quad (3)$$

with $\bar{x}$ the mean and SD is the standard deviation, as shown in Equation 4.

$$SD = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad (4)$$

x_i is the measurement data, $\bar{x}$ is the average of the measurement data, and n is the number of measurement data.

3. RESULTS AND DISCUSSION

Table 1 presents the results of measuring workers' body dimension data or anthropometry. Measurements are made based on static anthropometric measurements of workers in a sitting position. Body dimension data are measured based on workers who do lightweight brick-cutting work. Age and length of service are 26-33 years and 3-4 years, respectively.

Table 1. Body Dimension Data for Lightweight Brick-Cutting Workers

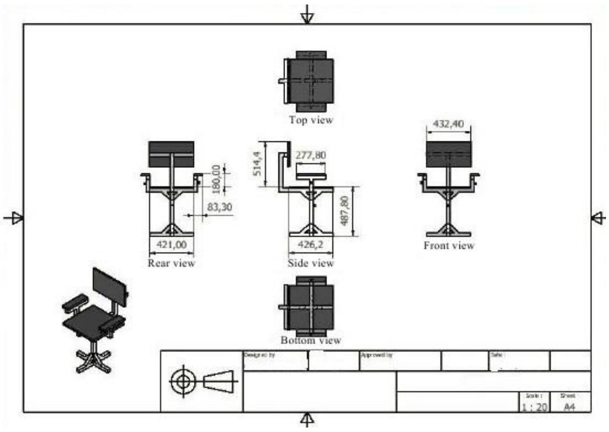
No	Data Type	Sample (cm)						
		1	2	3	4	5	Mean	Standard Deviation
1.	Popliteal Height	39.7	39.2	44.5	38.9	41	40.6	2.2919
2.	Buttock-popliteal Distance	41.3	42.7	46.1	39.8	43.2	42.62	2.3531
3.	Shoulder Width	42.1	42.9	46.2	40.4	44.6	43.24	2.2412
4.	Hip Width	37.7	37.6	42.9	41.5	41	40.14	2.3776
5.	Shoulder Height	50.1	49.9	56	49.3	51.9	51.44	2.7273
6.	Elbow Height	18	18.5	20.2	17.9	19.7	18.86	1.0359
7.	Arm Width	8.2	8.1	8.4	7.3	8	8	0.4183
8.	Arm Length	27.9	28.1	29.1	25.5	28.3	27.78	1.3535
9.	Length of the Sole of the Foot	23.5	24.1	25.3	23.1	25.4	24.28	1.0402
10.	Foot Width	9.4	9.3	10	9.2	9.7	9.52	0.3271

From the data in Table 1, the percentile value calculation is carried out to obtain the dimensions applied to redesign the work tool. The results of the calculation of the 5th percentile (P5), 50th percentile (P50), and 95th percentile (P95) values are presented in Table 2. The redesign uses data from Table 2 and as the dimensions of the new work tool. The results of the redesign are as presented in Figure 2. For the chair height, the design will add 10 cm to the height according to the footrest height.

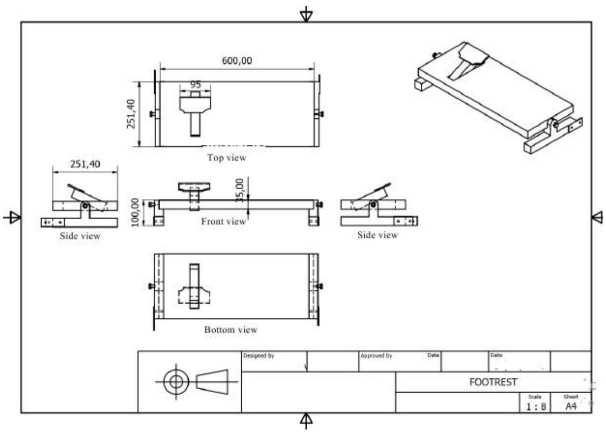
Table 2. Data for calculating the percentile value of lightweight brick-cutting worker

No	Data Type	P5 (cm)	P50 (cm)	P95 (cm)	Application
1	Popliteal Height	38.8	-	42.54	Chair Height
2	Buttock-popliteal Distance	-	42.62	-	Chair Length
3	Shoulder Width	-	43.24	-	Backrest Width
4	Hip Width	-	-	42.1	Seat Width
5	Shoulder Height	-	51.44	-	Backrest Height
6	Elbow Height	18	-	19.72	Armrest Height
7	Arm Width	-	-	8.33	Armrest Width
8	Sleeve Length	-	27.78	-	Armrest Length
9	Length of the Sole of the Foot	-	-	25.14	Footrest Width
10	Width of the Sole of the Foot	-	9.52	-	Width of Pedal Switching

(a)



(b)



(c)

Figure 2. a) Results of work tool redesign, b) and c) technical drawing (millimeter)

Figure 2 is the result of the redesign of Figure 1 using anthropometric data of male workers working in lightweight brick cutting. From Figure 2, it can be seen that the results of the redesign include changes in the position of the pedal switch on and improvements to the work chair. This redesign provides changes in the level of musculoskeletal complaints in workers. The results of tests conducted on the level of musculoskeletal complaints of workers using the Nordic body maps questionnaire showed a decrease in the level of complaints from using the new redesigned tool compared to using the old tool. This is shown in Figure 3.

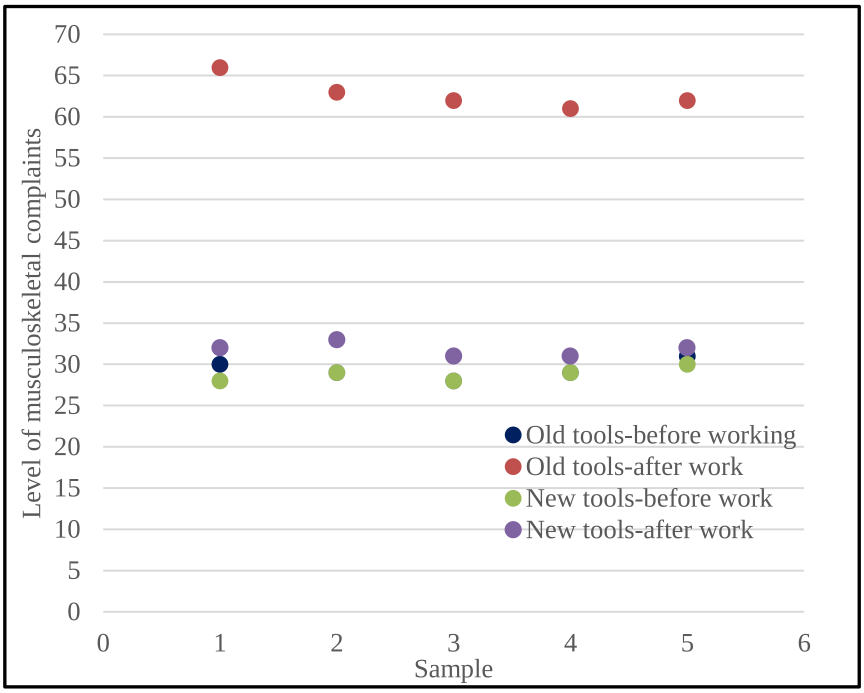


Figure 3. Comparison of levels of musculoskeletal complaints among workers

The decrease in musculoskeletal complaints in workers based on the condition of completion or after work was an average of 49.36%. When workers finish or work using old tools, the level of musculoskeletal complaints reaches an average of 62.8, with a range of 61-66. While using new tools gave a level of musculoskeletal complaints of an average of 31.8 with a range of 31-33. The level of musculoskeletal complaints with a total individual score of 50-70 has a moderate risk level and requires corrective action [11]. This shows that workers experience a moderate risk level and require corrective action on the tools used. The measurements before working on the old and new tools showed an average level of musculoskeletal complaints of workers of 29.4 with a range of 28-31 and 28.8 with a range of 28-30, respectively. This shows workers do not experience musculoskeletal complaints before working on the old or new redesigned tools. The level of musculoskeletal complaints with a total individual score of 28-49 has a low risk level [11]. Redesigning work tools based on workers' anthropometric data has been shown to have an impact on reducing workers' musculoskeletal complaints, in this case, in lightweight brick-cutting work. Workers do their work with a natural posture. This study is on the results of [20], which states that to minimize musculoskeletal injuries through natural work postures. In addition, the use of workers' anthropometric data creates an effective, comfortable, safe, healthy, and efficient work atmosphere [4]. The emergence of a natural work posture due to the application of ergonomics through measuring workers' anthropometric data, so that the level of musculoskeletal complaints can be reduced. This is in line with Olowogbon et al., that musculoskeletal disorders arise due to poor working posture in manual handling [9].

Harmony between work tools and workers is created by training workers in ergonomics. Based on the International Ergonomics Association, it is explained that ergonomics is a science related to the relationship between humans and other elements of a system and a profession that applies methods, data, theories, and principles to design in order to optimize the overall results of the system and human welfare [21]. The application of ergonomic principles to design work tools provides a sustainable, effective, comfortable, safe, healthy, and efficient way of working, and does not cause new problems after the tool is applied in a production process. Reducing musculoskeletal complaints can affect the level of productivity and quality of life of workers.This is in accordance with productivity calculated physiologically, namely the level of productivity influenced by production results compared to the level of musculoskeletal complaints. If the level of musculoskeletal complaints can be kept low, then the level of productivity will also be maintained optimally.

4. CONCLUSION

The application of anthropometric data to the redesign of lightweight brick-cutting tools resulted in a decrease in the level of musculoskeletal complaints in workers. The redesign was carried out only on the pedal switch and work chair because this was what caused complaints from workers. The changes made were able to reduce the level of musculoskeletal complaints in workers by 49.36%. Measurements using the Nordic body maps questionnaire showed that before working on the old and new tools, workers did not experience musculoskeletal complaints and were at a low-risk level. The average level of musculoskeletal complaints was 29.4 and 28.8, respectively. Workers using the tool before the intervention had an average level of musculoskeletal complaints of 62.8. Corrective action was needed regarding the tools used in the work. The improvements made to the pedal switch on the cutting tool and work chair were able to have an impact on the level of musculoskeletal complaints at a low risk level reaching an average of 31.8. This condition provides a comfortable working situation and a natural working posture. The results of the work tool redesign in this study can be applied in other places provided that the work tool conditions are similar and the workers are male. A wider sampling is needed with variations in male and female workers.

5. REFERENCES

[1] R.S. Bridger, *Introduction to the Ergonomics*, *Second Edition*. New York: Taylor & Francis, 2003.
[2] OSHA, *Ergonomics*, Available online: https://www.osha.gov/ergonomics (Accessed 9 November 2024).
[3] L. Benos, D. Tsaopoulos, and D. Bochtis, "A Review on ergonomics in agriculture. Part I: manual operations," *Applied Sciences*, vol. 10, no. 6, pp. 1905, 2020.
[4] T.N. Sari, R. Fil'aini, and D. Cahyani, "Analisis desain gagang cangkul berdasarkan antropometri petani pria dan beban kerja penggunanya pada lahan sawah di Kecamatan Wedung, Demak, Jawa Tengah," *Jurnal Optimasi Teknik Industri*, vol. 2, no. 2, pp. 66-71, 2020.
[5] D.M.N.D. Anggara, I G.N. Priambadi, and A.A.I.A.S. Komaladewi, "Perbaikan stasiun kerja sebagai Upaya mengurangi keluhan muskuloskeletal guna meningkatkan produktivitas perajin di Sutama Gamelan," *Jurnal Mettek*, vol. 9, no. 1, pp. 45-53, 2023.
[6] M. Rajendran, A. Sajeev, and R. Shanmugavel, "Ergonomic evaluation of workers during manual material handling," *Materialstoday: Proceedings*, vol. 46, no. 17, pp. 7770-7776, 2021.
[7] N. Evadarianto and E. Dwiyanti, "Postur kerja dengan keluhan musculoskeletal disorders pada pekerja manual handling bagiang rolling mill," *The Indonesian Journal of Occupational Safety and Health*, vol. 6, no. 1, pp. 97-106, 2017.
[8] L. Lady and S.F. Nuraeni, "Preventing musculoskeletal disorders due to manual material handling in the production process of clean water," *Journal Industrial Servicess*, vol. 10, no. 1, pp. 125-132, 2024.
[9] T.S. Olowogbon, R.O. Babatunde, E. Asiedu, and A.M. Yoder, "Prevalence and exposure to ergonomic risk factors among crop farmers in Nigeria," *Applied Sciences*, vol. 11, pp. 11989, 2021.
[10] M. Barneo-Alcántara, M. Díaz-Pérez, M. Gómez-Galán, A. Carreño-Ortega, and A.J. Callejón-Ferre, "Musculoskeletal disorders in agriculture: a review from web of science core collection," *Agronomy*, vol. 11, pp. 2017, 2021.
[11] Tarwaka, *Ergonomi Industri: Dasar-dasar Pengetahuan Ergonomi dan Aplikasi di Tempat Kerja*, *Edisi 2 dengan revisi*, Surakarta: Harapan Press, 2019.
[12] A. Kristanto, S.C. Widodo, "Perancangan ulang alat perontok padi yang ergonomis untuk meningkatkan produktivitas dan kualitas kebersihan padi," *Jurnal Ilmiah Teknik Industri*, vol. 14, no. 1, pp. 78-85, 2015.
[13] S. Fiana, W.K. Sugandi, A. Thoriq, A. Yusuf, "Analisis antropometri petani dan aplikasinya pada desain alat pemanen manggis," *Jurnal Ergonomi Indonesia*, vol. 5, no. 1, pp. 25-31, 2019.
[14] I G. Santosa, I N. Sutarna, "Use of solar energy hybrid dryer with techno-ergonomic application to increase productivity of dodol wokers in Buleleng, Bali", *IOP Conf. Series: Journal of Physics: Conf. Series*, vol. 953, no. 1, pp. 012087, 2018.
[15] I G. Bawa Susana, "Rancangan ruang pengering berbasis ergonomi menurunkan keluhan muskuloskeletal perajin ikan," *Dinamika Teknik Mesin*, vol. 6, no. 1, pp. 15-21, 2016.
[16] L.K. Wilogo, T.I. Oesman, J. Susetyo, "Perbaikan alat penuang cairan logam berdasarkan pendekatan ergonomis mengurangi resiko cedera fisik pada karyawan di PT. Aneka Adhilogam Karya Klaten," *Prosiding SENDI_U*, pp. 625-632, 2019.
[17] I W.G. Suarjana, M.F. Pomalingo, and B.R. Parhusip, "Penerapan ergo-mechanical design sebagai upaya peningkatan kualitas Kesehatan pekerja CV. Victoria," *Jurnal Abdimas Jatibara*, vol. 1, no. 1, pp. 73-83, 2022.
[18] Occupational Safety and Health Administration, *Ergonomics: solutions to control hazards*, Available online: https://www.osha.gov/ergonomics/control-hazards (Accessed 1 August 2024).
[19] I G. Bawa Susana, I K.P. Putra, and I G.A.K. Chatur Adhi Wirya Aryadi, "Aplikasi alat bantu ergonomis pada kerja manual berdasarkan kajian ergo-mechanical untuk petani kecil," *Energy, Materials and Product Design*, vol. 3, no. 1, pp. 176-183, 2024.
[20] I. Pratiwi, Purnomo, R. Dharmastiti, and L. Setyowati, "Evaluasi resiko postur kerja di UMKM gerabah menggunakan metode quick exposure checklis," *Seminar Nasional IENACO*, pp. 132-138, 2015.
[21] International Ergonomics Association (IEA), *What is Ergonomics*, Available online: https://iea.cc/what-is-ergonomics/ (Accessed 8 October 2024).