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Redesign of workstations to minimize musculoskeletal disorders for guitar workers in Indonesia

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ABSTRACT

This study aims to determine and analyze body parts that experience musculoskeletal disorders (MSDs) and muscles that experience fatigue in guitar-making workers. The method used is the Nordic Body Map (NBM) to determine MSDs complaints, including complaints of pain in 28 parts of the worker's body, and the Muscle Fatigue Analysis (MFA) method to determine muscle fatigue that occurs in each part of the body by determining the level of effort, duration of work, and frequency of work movements. The results of research using NBM were 2 workers with high risk, 3 workers with medium risk, and 7 workers with low risk. The results of the MFA method were that 3 workers experienced muscle fatigue in the very high category with priority in the neck, back, shoulders, right arm, wrist and feet. Efforts to minimize the risk of MSDs by redesigning work facilities using SolidWorks software and reducing the risk of muscle fatigue by improving work facilities, improving the layout of the production floor, and encouraging workers to stretch their muscles and exercise regularly.

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1. INTRODUCTION

Musculoskeletal disorders (MSDs) or injuries to muscles, nerves, tendons, bones, bone joints, and cartilage induced by work tasks, are some of the most common injuries that employees experience when doing manual material handling (MMH) tasks [1]. Inappropriate MMH operations might result in employee losses and even accident. MSDs prevention involves removing or reducing worker exposure to physical hazards [2]. It is required to conduct a systematic study and prioritize the essential ergonomics in order to assess the amount of exposure to musculoskeletal risk factors [3, 4] . MSD research was also carried out by [5] on barecore SMEs using the Job Strain Index (JSI) and Assessment Repetitive Task (ART) Tool methods.

Workers at SMEs Robin Gitar Sukoharjo Indonesia use tools and machinery to perform numerous tasks in the manufacturing process. Workers' tasks are characterized by the use of a lot of hand muscles, repeated activity, and uncomfortable body postures. In addition, the workweek runs from Monday to Saturday, from 08.00 to 16.00

WIB, with an infinite leisure hour in between. Robin Gitar was chosen because it is one of the guitar SMEs that employs many workers and makes a quite wide range of guitar types in Sukoharjo Regency. The approximately 300 units of guitar production target per day leads to workers often experiencing fatigue in fulfilling it. Long-term fatigue leads to workers often feeling pain in certain parts of their body, especially in the production of guitar necks and bodies. Physiological measures have not been used to assess the health of workers until today. Work performed for 8 hours in a standing posture, sitting with a bent body position, crouching, and performing repeated actions, especially the upper body such as elbows, forearms, hands, back, neck, and wrists, can all increase the risk of injury in the long run. As a result, workers complain of back, shoulder, neck, and hand pain. To minimize musculoskeletal disorders and reduce fatigue in workers, it is necessary to research and analyze the position of workers making musical guitar instruments at the Robin Gitar Sukoharjo Indonesia, which can cause MSDs, using the Nordic Body Map (NBM) method and the Muscle Fatigue Analysis (MFA) method. Additionally, workers' productivity will rise.

The Nordic Body Map (NBM) approach is a technique that involves studying a body map for each body part [6]. You may observe the intricacies of the muscles that are experiencing complaints ranging from little discomfort (slight pain) to severe misery using NBM [7]. The NBM is a basic ergonomic measurement instrument that may be used to determine the root of musculoskeletal diseases [8]. The muscles' portions in pain may be observed with NBM, with pain levels ranging from mild discomfort to severe agony.

Rodgers developed the MFA method, also known as a functional work assessment methodology, as a tool to measure the degree of fatigue built in the muscles in diverse activity patterns within the first five minutes of labor [9]. The MFA approach confirms that workers' posture and position during work greatly contribute to muscular fatigue [10]. The MFA approach is based on the idea that if you become fatigued rapidly, you're more likely to get injured and inflamed [11]. The neck, shoulders, back, arms/elbows, wrists/hands/fingers, knees, and ankles/feet/toes are all assessed using this procedure [11]. This approach considers three factors, namely the amount of effort, the length of effort, and the repetition of attempts in each part of the body, to identify the priority level of corrective action, namely low, medium, high, and very high [12].

The goals of this study are to identify worker complaints of MSDs, analyze the risk of workers' work postures using the NBM and MFA methods, and provide recommendations for improvement based on the results of measuring the level of ergonomic risk for workers at Robin Gitar Sukoharjo SMEs in order to reduce or minimize worker injury.

2. MATERIALS AND METHODS

2.1. Research Subject and Object

The entire workforce at each workstation in the guitar making center located in Sukoharjo Regency, Central Java Indonesia with the condition that they are 15-64 years old referring to the definition of the workforce according to The Ministry of Trade of the Republic of Indonesia (2013) has a minimum working period of one year is the subject of this study. In accordance with the provisions of Article 2, Section 1, of the Convention, Indonesia attaches a statement that stipulates that the minimum age limit for being permitted to work in force in the territory of the Republic of Indonesia is 15 (fifteen) years old [13]. In the guitar production process, Robin Gitar includes four workstations: body station, neck station, fingerboard station, and finishing station. During the hours of 08.00 - 16.00 Western Indonesian Time, this study monitored the general work activity at each workstation.

2.2. Research Procedure

Direct observation, interviews, questionnaire filling, and documentation were used to collect data. Workers' job activities are photographed or videotaped as part of the documentation process. The official website of Indonesian anthropometry, https://antropometriindonesia.org, was used to gather anthropometric data. Worker identity, worker complaints, and worker complaints are among the data required for data processing using the NBM method. Body posture data, work effort level, work effort data, work duration data, and work movement frequency data are all necessary for data processing utilizing the MFA approach [14].

In the NBM technique, data was processed by first delivering a questionnaire to the operator to determine the operator's concerns. NBM is capable of identifying and assessing pain complaints [15]. The NBM questionnaire is the most widely used questionnaire used to investigate discomfort in workers because it is standardized and

well-organized [16]. Then, using the answers of the questionnaire, participants were scored on a scale of 1 (not sick), 2 (somewhat unwell), 3 (sick), and 4 (very sick). The total score acquired from each worker has been calculated as a consequence of the scoring [17]. Then, depending on the individual's total score, classify the level of risk [7].

The MFA approach will be used to process the data, which will be based on the overall score of NBM persons with moderate to extremely high-risk levels. (1) Identifying problems from a work activity; (2) selecting job assignments for analysis; (3) determining the level of effort used for each body part; (4) determining the duration of work for each work intensity of each body part; (5) determining the frequency of work at the same work intensity for each body part; (6) determining the frequency of work at the same work intensity for each body part; (6) Determine the priority of score changes using the three-number ranking generated in steps 3–5; (7) Determine the priority of score changes from highest to lowest; (8) Develop several strategies to address the leading causes of high scores; (9) Redefine the sequence of tasks in all body parts to determine the impact of changes related to work comfort and complaints.

3. RESULTS AND DISCUSSION

3.1. NBM Method Analysis

The NBM questionnaire was collected by direct interview with 12 workers as respondents. In order for the results to be valid, the interview was done personally, and the researcher gave a mark (V) on the questionnaire according to what the worker felt at work. NBM According to Table 1, three employees have a skeletal muscle risk level of "moderate" indicating that action may be necessary for the future, and two workers have a skeletal muscle risk level of "high" indicating that urgent treatment is required.

Table 1. MSDs risk level classification based on individual total score

No	Name	Total Individual Score	Risk Level MSDs
1	Worker 1	71	High
2	Worker 2	75	High
3	Worker 3	58	Moderate
4	Worker 4	43	Low
5	Worker 5	62	Moderate
6	Worker 6	70	Moderate
7	Worker 7	49	Low
8	Worker 8	33	Low
9	Worker 9	34	Low
10	Worker 10	48	Low
11	Worker 11	44	Low
12	Worker 12	41	Low

3.2. MFA Method Analysis

Rodgers and Williams created the MFA approach in 1987 as a functional job evaluation methodology to explain worker pain [11]. The MFA technique of data processing is carried out by choosing personnel at work stations based on NBM estimates with very high, high, and medium risk categories. Table 2 contains information on respondents who had very high, high, or moderate NBM scores.

The MFA method uses the MFA worksheet as a reference which is used to determine the assessment of the movement of the limbs from the neck to the ankles in workers who are carried out in categories based on the level of effort made, the duration of the action made, and the frequency of the effort made. The business-level category consists of low-1, medium-2, and heavy-3 levels. Determination of the duration of the work carried out by workers there are four scores, including a score of 1 (< 6 seconds), a score of 2 (6-20 seconds), a score of 3 (20-30 seconds), and a score of 4 (> 30 seconds). While determining the frequency of effort carried out, there are also four scores,

namely a score of 1 (<1/minute), a score of 2 (1-5/minute), a score of 3 (>5-15/minute), and a score of 4 (>15/minute). Category scores increase fatigue for the three-digit rating (Effort, Duration of Continuous Effort, and Frequency). The following is the processing of Worker activity data using the MFA method based on high and moderate risk scoring on the NBM method.

Table 2. Selection of workers for the MFA method

Worker	Workstation	Activity	Total NBM Score	Risk Level
1	Body	Body Side Installation Braces Installation Finishing Body	71	High
2	Body	Closing Installation Top and Back Installation	75	High
3	Body	Body Side Installation Linings Installation	58	Moderate
5	Neck	Wood Cutting Finishing Neck	62	Moderate
6	Neck	Drawing Sketch	70	Moderate

Activities of each process that will be analyzed to be prioritized for improvement are activities that have accumulated effort + duration + frequency = high or very high. The recapitulation of MFA data processing results can be seen in Table 3.

Table 3. Recapitulation of MFA data processing results

Worker	Activity	Part of Body	Before		After	
			Score	Priority	Score	Priority
1	Baraces Installation	Neck	243	Very High	112	Low
		Back	243	Very High	212	Low
	Finishing Body	Hand/Fingers	141	Very High	132	Moderate
		Right Elbow	322	High	122	Low
3	Body Side Installation	Leg/Knee	341	Very High	111	Low
		Ankle foot	341	Very High	111	Low
	Linings	Leg/Knee	341	Very High	111	Low
		Ankle Foot	341	Very High	111	Moderate
5	Wood Cutting	Hand/Fingers	242	Very High	232	Moderate
		Back	322	High	112	Low
	Finishing Neck	Neck	223	High	123	Moderate
		Shoulder	223	High	123	Moderate
		Back	223	High	123	Moderate

Based on the complaints of MSDs on the resulting MFA score, suggestions for improvement of each work activity can be made to reduce the risk of MSDs as follows. The same thing is also done by [18] for paving lifting and paving transportation activities.

3.3. Improvement Worker 1

Braces Installation Activities. Previously, the worker's posture was unsuitable because he or she was seated on the floor without a table. As a result, it's critical to keep the neck down and bend the torso when putting on braces so that the eyes and hands may accomplish their full range of motion. After that, provide a table with a tilt angle of 150, with a length of 40 cm x width 47.84 cm x 24 cm and a tilt angle of 150, to see manual work that

requires the use of hands, the work surface must be placed at an angle of 15 degrees, any slope greater than this is not recommended due to a lack of arm support [19]. Workers who had previously worked in a sitting position on the floor without a table were given a tilting table as an upgrade, the results of worker interviews indicated that they could reduce MSDs complaints (see Figure 1 (a)).

(a) (b)

Figure 1. Worker 1 (a) brances installation; (b) finishing body

Finishing Body Activities. Previously, the layout/location of the item to be taken is less ergonomic, and the duties must be accomplished over a long period. Because of regular procedures that cannot be prevented, Worker 1 must exert a great deal of effort when performing body completing activities, such as rotating the body, lifting objects with extended arms, and wrists performing long-duration activities. Following that, the risk of injury to the right arm and elbow was eliminated. Provision of a table with the dimensions of a Worker's chair: 100 cm long, 55 cm wide, and 44 cm high. The dimensions of the workbench are obtained from data that has been processed from Indonesian anthropometry from the website [20]. This is to avoid awkward positions like reaching too far with the right arm/elbow when picking up items. To begin, where on the Worker's back is the object that necessitates the Worker spinning to reach the object, which is too far away and dangerous? With a maximum capacity of four bodies, the table is utilized to place the body (item) that will be used in the finishing process. The table should be positioned directly to the right of the worker, so that he or she may easily grasp it with the operator's hand to take a sitting position (see Figure 1 (b)).

Repairing a Wrist, Hand, or Finger is a risky proposition. Execute management engineering in education and training, including balancing work and relaxation schedules and providing thorough monitoring [21]. To avoid working for lengthy periods, workers must take a brief break in the middle of their tasks [22]. When the same body part performs the same activity again without rest or a chance to rest, the danger grows [23]. Muscles can relax and weariness can be relieved by rest [22].

3.4. Improvement Worker 3

Body Side Installation. Previously, work posture workers crouch and take a long time to complete tasks. As a result, Worker 3 must put out a large amount of effort on the body section of the legs to maintain the body during body side installation operations. Following that, the employee sits on the floor with his legs straight out in front of him. This aims to reduce problematic postures that support the body for an extended period, such as feet, ankles, and toes. The Worker begins in a crouched position, which requires the Worker to support his or her weight on both legs, this can reduce body stress on the feet and ankles (see Figure 2 (a)).

(a) (b)

Figure 2. Worker 3 (a) body side installation; (b) linnings installation

Linings Installation. Work posture workers used to be less ergonomic, and the activities they performed took a lengthy time. As a result, worker 3 must exert a great deal of effort on the body section of the legs to support the body when installing linings. After, A table with a length of 40 cm, a width of 47.84 cm, and a tilt angle of 150 cm are provided. The dimensions of the workbench are obtained from data that has been processed from Indonesian anthropometry on the website [20]. To see manual work that requires the use of hands, the work surface should be set at a 15-degree slant; a steeper slope is not advised due to the absence of arm support. This seeks to reduce unnatural postures like the back being constantly stooped over and the neck being constantly bent down to access the thing. Workers who were previously working in a sitting position on the floor without a table were offered an upgrade in the shape of a tilting table. Worker activity 3 requires the installation of linings to modify the Worker's work posture to sitting on the floor with legs spread out straight ahead, in addition to the proposed improvement design in the form of a table. This tries to decrease awkward postures such feet and ankles/toes that support the body for an extended period. At first, the Worker is in a crouching position, which forces the Worker to hold his or her body weight on both legs (see Figure 2 (b)).

3.5. Improvement Worker 5

Wood Cutting. Previously, cut item layout/placement was less ergonomic, and activities took a long time to complete. As a result, Worker 5 must expend considerable effort when doing woodcutting activities such as twisting the body, tossing the cut object to the back of the body, and performing activities with the wrist for an extended period, because the standard process cannot be avoided. Following that, repairing the possibility of a back injury. Boxes for containers are being added. The container box is 25.5 cm in length, 47 cm in width, and 59 cm in length. The dimensions of the container box are obtained from anthropometric data that has been processed [20]. Place the container box on the right side of the machine. This is done to avoid awkward postures like the back rotating continually to throw away sliced materials. The worker who first tossed the object cut by turning the body back provided an improvement in the shape of a container box under the right side of the machine, obviating the necessity to turn the back (see Figure 3 (a)).

It's dangerous to repair a wrist, hand, or finger. Implement management engineering in education and training, which includes balancing work and relaxation schedules and ensuring thorough monitoring [21]. Workers must take a small break in the middle of their jobs to avoid working for prolonged amounts of time [22]. The hazard increases when the same body part repeats the same activity without rest or the opportunity to relax [24]. Resting allows muscles to relax and fatigue to subside [22].

(a) (b)

Figure 3. Workers 5 (a) wood cutting; (b) finishing neck

Finishing Neck. The arrangement of chopped and uncut things used to be less ergonomic. As a result, when Worker 5 performs neck finishing activities, the back must be bent to pick up and place items, the right shoulder must be far away from the body to reach goods, and the neck must be constantly bent down to see objects when picking and placing objects. Added tables and container boxes on both sides of the worker to improve the design of the neck workstation for finishing neck duties, reducing the risk of injury to the neck, right shoulder, and back in this situation. After, To complete neck surgeries, it is advised that the neck workstation be upgraded to incorporate a table and a container box. The table is 61 cm in length, 49 cm in width, and 45 cm in height. Figure 3 shows the dimensions of a container box with dimensions of 59 cm long, 47 cm wide, and 25.5 cm high. To the right and left of the personnel are tables and container boxes. When taking up and setting items, this is designed to prevent uncomfortable positions such as the neck, right shoulder, and back. Workers who must bend their bodies to place and pick up items are given alternatives in the shape of tables and container boxes on the right side for unfinished objects and on the left side for finished objects, which eliminates the need to bend the neck, right shoulder, and back (see Figure 3 (b)).The majority of the body areas at high to extremely high risk in this study, according to data processing using the MFA approach, are in the upper body, including the neck, back, shoulders, and wrists. Legs are also a source of the complaint. The dimensions of the workbench are obtained from anthropometric data that has been processed [20].

According to research on furniture firms [22], two criteria cause high-risk activity when employing the MFA approach, namely the kind of business and the term of the business. Various sorts of effort workers must perform grips, including difficult postures that should be avoided, such as head forward, shoulders supporting weight with hands away from the body, crouching position, and fingers must do grips [25]. Improvements to activities include shifting assembly operations to the table, requiring workers to take a break in the middle of their shift to relax muscles, and modifying the movement of workers while doing activities to reduce the risk of injury. Vitamin D, a fat-soluble vitamin that stimulates calcium and phosphorus absorption in the gut, maintaining normal serum calcium and phosphate concentrations and permitting normal bone mineralization, development, and remodeling, can aid with poor posture [26]. Vitamin D has the potential to regulate a wide range of cellular functions in addition to calcium and bone homeostasis.

Upper printing activities, designing and drawing patterns, and sewing patterns all have a significant risk, according to research [27] on producing leather shoes using the MFA technique. Improvements to the design of tables and chairs, as well as alterations to the placement of items, were introduced in the activities. As research conducted by [28] the provision of ideal workstation components which ought to be tailored to each worker and regularly serviced, as well as the implementation of policies targeted at improving employees' health. Workers should be actively involved in executing and maintaining these measures.

4. CONCLUSION

Based on the findings of data processing and analysis using the NBM and MFA methodologies, it can be determined that the acoustic guitar manufacturing process at the Robin Gitar Sukoharjo SME comprises 19 work activities distributed over four workstations, each with its own set of hazards. The 12 employees were studied using the NBM approach, and it is well known that each worker has a varied risk of harm. The investigation discovered that five workers had a significant chance of having their activities estimated using the MFA approach. While the results of the study using the MFA method were carried out on five workers with a total of ten activities, namely body side installation activities, linings installation activities, braces installation activities, closing installation activities, top back body installation activities, pattern drawing activities, wood cutting activities, and neck finishing activities, based on the calculation of the NBM method. Offering tools in the form of an ergonomic table at the workstation, modifying the layout/layout of the workstation, training and education to workers on Occupational Health Safety and ergonomics systems are some of the ideas made to the company owners for improvement.

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