RESEARCH ARTICLE

Application of Ergonomic Workplace Model to Design an Industrial Ergonomic Trolley for the Wood Furniture Industry

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Abstract

Wood furniture industry is an industry that fastest growing sub-sector in Malaysia. Although the industry has grown tremendously over the years, the working environment is still poorly designed. This paper presents an ergonomic workplace model that was developed based on anthropometric measurement to reduce work-related musculoskeletal disorder risk factors. A model of the integration between statistical approach and anthropometric measurement has been developed based on the application of the ergonomic approach and selected quality tools such as stable stadiometer, measuring tape, and laser rangefinder. The traditional anthropometric instrument was used in this study to measure the worker's body. Four anthropometric measurements of six male industrial workers were measured: stature height, arm span, forward arm reach, and waist height. Subsequently, the anthropometric measurements were combined with a statistical approach to design an industrial ergonomic trolley-lifter for wood industry workers. The average of the statue arm for 50th percentile user was 170.46 cm, the arm span was 96.33 cm, the forward arm reach was 89.55 cm, and the waist height was 170.7 cm. The obtained results show that the developed model potentially improves the production's performance and enhance safety and comfort of workers.

Keywords: *ergonomic workplace model, anthropometry, design, industrial trolley-lifter, wood furniture industry*

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Introduction

Improved human–workplace designs, such as a well-accommodated workstation (workbench and tool shelf) can enhance workers' productivity, comfort, and safety. Designing a product for workers involves consideration of the workers' machines, tools, and work environment. Therefore, a reliable and valid anthropometric database is crucial to determine workers' safety and comfort. Anthropometry refers to the scientific study of measurement and proportions of the human body. Several studies obtained employees' anthropometric data (1–3) and the application of the data was investigated (4–6). Anthropometric measurements measure the human body structure size and strength (7). Anthropometric measurements enable the designer to modify their design size and measurement to accommodate the human body size and shape.

The integration of ergonomic principles into workplace design could numerously benefits for both workers and employers. An ergonomic workplace could offer a better work environment to workers which resulting in enhanced productivity, that could be beneficial to employees to increase their sales. Thus, it is employers' responsibility to provide a safe and healthful workplace for their workers as well as workers' responsibility to follow the guideline provided. One of the most important aspects on workplace ergonomic is fitting a job to a person. Hence, it is very crucial to identify the risk of ergonomic among workers for the purpose of implementing the ergonomic intervention to workplace and workplace equipment. Studies found that optimize the interaction between individuals and their work environment by ergonomic intervention could maximise the efficiency (Martimo et al., 2010; Rostami et al., 2022; Ting et al., 2019). Radin Umar et al., (2019). have developed an ergonomic trolley-lifter, based on the participatory inputs from end users and ergonomic parameter, which allows for a better working posture for sheet metal handling task. Through this study, the use of the developed prototype reduced cycle time which up to 47% and decrease manpower utilization from two to one. Similar study with efficiency (Martimo et al., 2010; Rostami et al., 2022; Ting et al., 2019). Radin Umar et al., (2019), they have developed an efficient material handling equipment for the finishing department of a garment industry. In this study, the implementation of trolley in the finishing department could decrease the manpower from 23 to 11, which increased the worker's productivity to 109%. Another study found that the trolley designed with anthropometric approach would increase productivity by 80% (Dinata et al., 2024). In study by Talapatra et al., (2019), they found mismatch between trolley dimension and anthropometric data. The findings of this study address a major need in dimensions for the design of an industrial trolley to increase comfort and efficiency of the workers. Evidently through these studies, a well-designed workplace would demonstrate an organization's commitment to their well-being, leading to increased job satisfaction, efficacy and productivity of workers.

In the wood furniture industry, most tasks involve lifting an object from one machine to another machine where the worker tends to lift in an improper body position. For example, the three work stages are described as follows: wood board cutting by band saw (Figure 1), acrylonitrile butadiene styrene (ABS) installation on the side of the wood board (Figure 2), and drilling (Figure 3). Figure 4 illustrates the stages of lifting activity. Among the aforementioned activities, the worst is the repetitive object lifting. In this condition, workers are required to lift wood boards and place them on the floor repeatedly based on the number of boards required for a specific piece of furniture. Nevertheless, in the existing condition (see: Figure 4), the workers exhibit awkward posture and are required to bend, which exposes them to a high risk of injuries, and prolonged musculoskeletal disorders (MSDs), specifically low back MSDs. Handling manual material with inappropriate tools and poor posture will lead to physical discomfort (Hilmi et al., 2024; Rajendran et al., 2021). Low back pain is one of the most common MSDs (Basakci Calik et al., 2020; Delitto et al., 2021; Zhao et al., 2022) and its incidence is high in adults. Moreover, low back pain is also widespread among workers who lift objects (Salleha & Sukadarina, 2018; Widia et al., 2016). In fact, repeated lifting can increase the risk of back and shoulder injury.

Figure 1: Wood Board Cutting by Band Saw

Figure 2: Installation of ABS

Figure 3: Drilling

Figure 4: Lifting Activities in the Woodworking Industry

Figure 5: Woodworking Area

Figure 5 depicts the working environment in a woodworking workshop. Based on the lack of ergonomics in the aforementioned activities, it is important to redesign the workplace or equipment with anthropometry data appropriate to the workers to ensure safety and comfort and minimise injuries. The purpose of this study was to design safer and ergonomic equipment for the woodworking industry based on the application of the anthropometry approach. An effective equipment and tool model was designed integrating the statistical approach and anthropometric measurements of workers' bodies.

Material and Methods

Anthropometric Measurements

This study was conducted with a small, targeted convenience sample that represent the number of workers on the lifting floor. The respondents' information sheet and consent letter were distributed to the workers to obtain their permission before performing these tasks. A total of six male industrial workers aged between 20 and 40 years were included in this study. Each participant's anthropometric measurements were obtained with the following four body measurements: stature height, arm span, forward arm reach, and waist height. The stature height and waist height were measured using the SECA 217 stable stadiometer (Figure 6). Arm span and forward arm reach were measured using measuring tape (Figure 7) and a laser rangefinder (Figure 8), respectively. Figure 9 illustrates the anthropometric measurements measured.

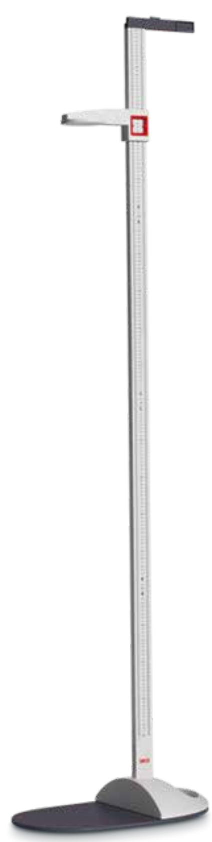

Figure 6: The SECA 217 Stable Stadiometer

Figure 7: Standard 8-Metre Measuring Tape

Figure 8: Bosch GLM 40 Professional Laser Rangefinder

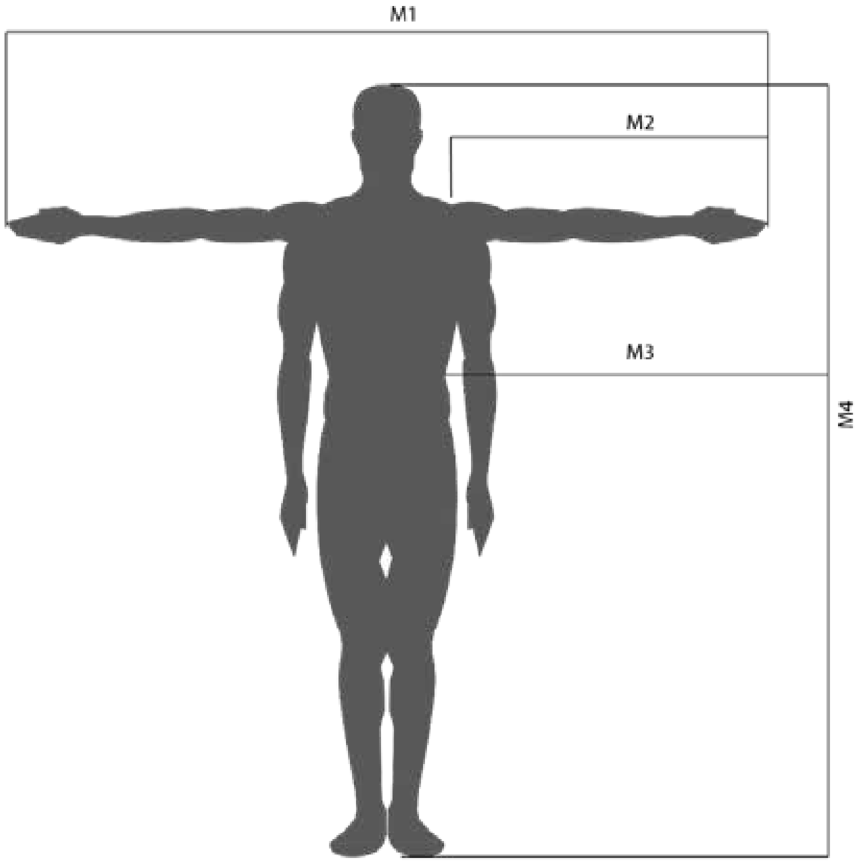

Figure 9: Acquired Anthropometric Measurements

Results and Discussion

Table I presents the statistical analysis results of the anthropometric measurement. An anthropometric measurement consists of three categories (5th, 50th, and 95th percentile indicating the smallest, average, and largest size, respectively). Table II depicts the anthropometric category evaluation, based on which the 50th percentile was selected as it potentially fitted the proposed industrial ergonomic trolley-lifter working design.

Table 1: Statistical Analysis Results of Body Measurements.

Body measurement (cm)	**Mean**	**SD**	**Min**	**Max**
Stature height	170.46	5.93	163.8	178.9
Waist height	96.33	4.02	92.6	103.3
Forward arm reach	89.55	2.68	85	91.5
Arm span	170.7	7.48	164.1	184.8

Table 2. Anthropometric category evaluation (18).

Category	Explanation	Justification
5th percentile	Shortest height	Best fitted for the shortest group. The tallest group is required to stretch their arms down, which causes hand discomfort.
50th percentile	Average height	Best fitted for both the tallest and shortest groups and requires minimal hand movements.
95th percentile	Tallest height	Best fitted for the tallest group. The shortest group is required to lift their arms, which causes awkward posture.

The measurements in the preceding section were calculated based on the averaged data from the industrial workers. An industrial ergonomic trolley-lifter was designed based on the 50th percentile, which was considered the best-fit measurements for all workers in the lifting section. The proposed trolley-lifter was designed based on the 50th percentile to provide comfort and proper positioning for workers when performing work tasks, such as lifting objects and sorting boards. The proposed trolley-lifter (see Figure 10) featured handles on both sides, industrial-standard wheel size, and a durable deck.

Figure 10: The Measurements of the Proposed Industrial Ergonomic Trolley-Lifter

In this study, the application of the anthropometric approach to design a working industrial trolley for lifting activities in the woodworking industry is detailed. In this study, stature height, arm span, forward arm reach, and waist height were measured. The stature height was measured to establish the overhead compartment height while the arm span was used to determine the left and right reach and work-top width. The forward arm reach was used to establish the work-top depth and front reach. Lastly, the waist height was used to determine the work-top height. Figure 11 presents the ergonomic workplace model in graphical representation.

Figure 11: The Ergonomic Workplace Model in Graphical Representation.

The average measurement (the 50th percentile) was calculated to obtain the average size and to ensure that the space would accommodate most workers. A good workspace should consider the limitations of body movement and measurements (Hignett & McAtamney, 2000). The manufacturing industry uses various industrial standard trolleys. Poor industrial trolley design is the most frequent cause of occupational injuries, such as low back and muscle sprain (Dube et al., 2022; Sokhibi & Alifiana, 2019). For example, substandard design, such as handle height and poor mismatch, can lead to excessive muscular loads.

Handle height is another aspect to consider when designing an industrial trolley. In the proposed design, the handle is placed on the side of the work-top based on waist height to facilitate pushing and pulling. This agreed with Kwong (2010), who stated that handle height must be maintained between elbow and waist level during pushing to yield optimal force capability. Lee et al., (1991) reported that an optimal handle height of approximately 1090 mm was better for pushing to reduce lower back pain.

The implementation of the developed model would be of major importance to workers in the selected production area. For example, the development of a conveyor system that transport parts from one production stage to another would bring optimization of production (Salawu et al., 2020). Similar study of the development of mechanism for straight forward sheet lifting trolley for laser cutting, which may carry objects up the steps with less effort compared to manual (Dube et al., 2022) The proposed design might minimise body fatigue and optimise production flow efficiency. Conversely, poor design (mismatch between human anthropometry and product design) may lead to discomfort, pain, and potentially increase MSD risk. The developed product in this study will aid production performance improvement in industrial organisations and increase human productivity and quality in the industrial field.

Conclusion

The purpose of this study was to design safer and ergonomic equipment for the woodworking industry based on anthropometry. An effective equipment and tool model was designed integrating the statistical approach and anthropometric measurements of workers' bodies. Through this model, the workers expected to have less discomfort while working because of the product designed to make it more suitable with body measurements. The further recommendation could be with large sample of participant as well as the validation of the workplace model.

Furthermore, there is an important need for anthropometry data for a Malaysian worker database to improve worker performance and productivity. The application of anthropometry measurements for workers could also prevent workplace MSDs. Therefore, further investigations should be conducted to compile a Malaysian anthropometry database and to design and redesign the workplace and equipment using anthropometry.

Disclosure Statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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