



Design of LPG transport aids to prevent musculoskeletal risks

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ABSTRACT

The Central Statistics Agency of Indonesia (BPS) has recorded an increase in the use of liquefied petroleum gas (LPG) by the public over the last seven years. This increase is due to the government changing its policy from using fuel oil to LPG. LPG is essential for the community as a kitchen fuel to meet their needs and for resale. Distributing LPG gas is crucial to meeting the community's needs. However, one of the distribution processes involves manual loading and unloading, which can cause musculoskeletal complaints. Therefore, tools that can facilitate work are necessary. This study aims to reduce the risk of musculoskeletal disorders by examining the working posture of transporting LPG gas at a LPG distributor in Indonesia. The study proposes a tool design to solve the problem of high work posture. The results of data processing and analysis show that the design of assistive devices can reduce the risk of work posture.

1. Introduction

The Central Bureau of Statistics, also known as Badan Pusat Statistik (BPS) in Indonesia, has noted an increase in the use of LPG every year for the last seven years [1]. LPG, which stands for Liquefied Petroleum Gas, is produced through the liquefaction and separation of gas at a specific pressure. The Indonesian government, through Pertamina, has implemented a policy to switch from kerosene fuel to LPG [2]. One reason for this change is that LPG is considered to be more efficient and environmentally friendly [3]. The distribution of LPG in Indonesia is carried out by Pertamina to various agents, who then redistribute it to small business units to be traded to meet people's needs. Filling cylinders with high-pressure gas and manually removing them can increase the risk of workplace accidents in companies [4].

Fajar Sidik Nurhidayah is a 3-kilogram LPG distribution agent in the Pandeglang Regency area. The company has workers consisting of office staff, drivers, and loading and unloading workers. Gas cylinder loading and unloading are done at the Bulk Elpiji filling station (SPBE) and the base. LPG loading and unloading workers have the task of transporting LPG manually,

both filled and empty gas cylinders [5]. According to a study, handling materials manually can cause pain in almost all workers' limbs. The study also found that workers who do not understand how to handle materials manually run the risk of developing musculoskeletal problems. Manual lifting activities can cause the risk of diseases, such as musculoskeletal disorders [6].

One study found that work posture was the biggest cause of musculoskeletal disorder complaints [7]. Unusual work postures can lead to muscle strain and fatigue, and if left unchecked, can result in damage [8]. Musculoskeletal symptoms can occur due to abnormal body postures, continuous work activities, and poor design of machines, tools, or work equipment. If left untreated, these symptoms can accumulate and result in temporary or permanent disability [9]. Musculoskeletal disorders can cause pain ranging from mild to severe [10], and if not addressed immediately, can interfere with concentration, cause fatigue, and ultimately reduce productivity [11].

In carrying out their work, LPG loading and unloading workers often complain of pain in their limbs, especially in the wrists, back and neck after loading and unloading activities.

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Figure 1. Existing loading and unloading

In addition, preliminary research was carried out to calculate manual lifting loads using the recommended weight limit (RWL) for workers, and the resulting loads that are currently occurring are in the high category.

LPG is available on the market in 3-kilogram, 12-kilogram, and 50-kilogram sizes. The distribution of LPG is very crucial because the community's need for LPG must be met, thus in the process of loading and unloading LPG, tools are needed to make work easier. By using a tool that is designed based on the results of measuring work posture, it is hoped that workers will not experience complaints or pain so that they can optimize the distribution system at Fajar Sidik Nurhidayah to the LPG base in Pandeglang Regency. The purpose of this study is to provide a proposal for the design of a manual lifting device for LPG cylinders at Fajar Sidik Nurhidayah. Figure 1 shows the existing condition of loading and unloading process at Fajar Sidik Nurhidayah.

The difference between this research and previous research is research using REBA [12], [13] with the research object of moving gas cylinders using REBA. One of the methods commonly used to measure body posture is RULA, body posture measurement using RULA has been carried out by [14], [15], [16], [17]. In contrast to research conducted by [18] who designed LPG trolleys but did not measure work posture in the design process.

2. Material and method

This research is qualitative in nature and involves only one worker as a sample, which is considered adequate for describing the population. The data collection process involved observation, interviews, and questionnaires. To measure the data, the NBM and RULA methods were employed. The NBM method involved asking the worker to fill out a questionnaire, while the RULA method involved taking pictures of the worker's posture when lifting gas cylinders. The CATIA software was utilized for data processing to calculate the RULA value. After obtaining the value for work posture, a tool was designed and the worker's posture was measured again while using the tool.

2.1. Problem formulation

After carrying out loading and unloading activities and being measured using the NBM, complaints of pain

arise in the limbs, especially the wrists, back, and neck. NBM to identify musculoskeletal disorder complaints experienced by workers due to work activities [19]. Apart from that, to find out the burden of recommendation that can or is safely lifted using the recommended weight limit (RWL), it turns out that what happened to Fajar Sidik Nurhidayah was in an unsafe condition. Complaints and unsafe load conditions if left unchecked will cause musculoskeletal disorders.

2.2. Calculation of Work Posture using Rapid Upper Limb Assessment (RULA)

To solve the problems identified above, the study involves calculating work postures and designing a tool to help workers with LPG loading and unloading. The Rapid Upper Limb Assessment (RULA) method is used to calculate work postures before and after the use of assistive devices. RULA is an established method for estimating the risk of musculoskeletal disorders, particularly those related to upper limb disorders caused by repetitive motions, strength-related work, and more. In previous studies, researchers have used manual forms to collect RULA data [20].

2.3. Tool design

At this stage, a tool will be designed to move 3 kg gas cylinders. The tool to be designed is a trolley. With a trolley, workers can move gas cylinders more efficiently, and reduce the risks posed by manually lifting gas cylinders. At this stage, there are three stages of designing assistive devices, namely determining the dimensions of the body, determining the size of the design of the assistive devices, and technical drawings for designing the assistive devices.

2.4. Determination of body dimensions

Determination of body dimensions is carried out by referring to Indonesian body dimension data. In determining body dimensions, it is done by determining which body dimensions are used in the design of assistive devices using Indonesian human anthropometry data. Anthropometric data collection with percentile grouping divided into 3, namely 5th, 50th, and 95th. The stage of determining the size of the tool is carried out after the anthropometric body dimensions are obtained. The function of this stage is to improve posture during activities so that worker comfort can be achieved. The calculations carried out to determine the design size of the tool are determining the height of the handle and determining the width of the handle.

2.5. Design

This technical drawing will make it easier to simulate working posture measurements after using the tool. Technical drawings for designing tools are done using AutoCAD software.

3. Results and discussions

3.1. Questionnaire Result

The results of the NBM questionnaire administered to workers revealed complaints of pain and discomfort in the neck, arms, wrists, back, and waist. This is attributed to workers lifting two gas cylinders at the same time, one in each hand, and bending down when placing the gas cylinder on the ground. Similar complaints have been reported by workers carrying wood, who experience neck pain due to bending down when collecting wood [21]. Workers who manually lift sugar also report complaints including pain in the shoulders, back, waist, knees, feet, calves, arms, and neck [22].

3.2. Existing work posture

The current work posture involves measuring the posture of carrying gas cylinders to storage locations. Right and left body posture of the activity of bring gas canisters is 6 based on the calculation using CATIA software. A score of 6 indicates that further observations and adjustments are necessary soon. The current body posture falls under the high-risk category. The activity of carrying gas cylinders has a score of 6 for each body part. This could be because both hands are used to lift the gas cylinder, which weighs approximately 8 kg, causing strain on the forearms, standing straight on both feet, and gripping the handle of the gas cylinder with the hands, which results in a score of 6 for the wrists and hands. The work posture is known to have an impact on the emergence of musculoskeletal complaints [23] and workers' activities [24]. According to [25], the load factor has an effect on musculoskeletal complaints, and there is a very strong correlation between work posture and complaints of musculoskeletal disorders (MSDs) [26].

3.3. Tool design

At this stage, a gas cylinder trolley will be designed to move 3 kg gas cylinders. The trolley is intended to enable operators to move gas cylinders more efficiently and reduce the risks associated with manual lifting. The design process will involve three stages: determining the body dimensions, determining the tool size, and creating the tool design drawings.

In determining body dimensions, it is done by determining which body dimensions are used in the design of the trolley aids, using Indonesian human anthropometry data.

Table 1. Indonesian anthropometric data on design of trolley handle

No.	Dimension	Provision	Size (mm)
1	D4 (elbow height)	Handle height	118.17
2	D17 (shoulder width)	Handle width	38.75

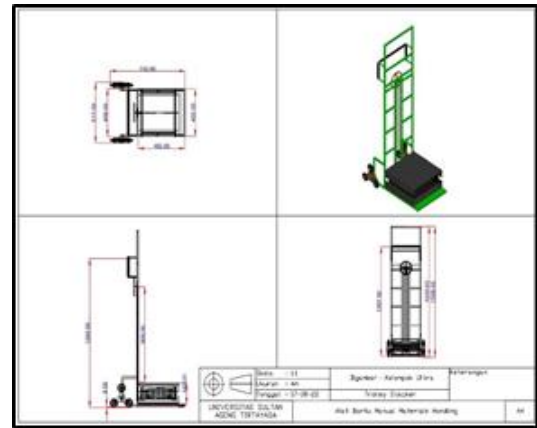


Figure 2. Trolley stacker



Figure 3. Loading and unloading simulation

In product design based on anthropometry, supporting data is needed so that the design can produce good and quality output. Provisions to support this is to determine the body dimensions that support the product so that it is designed ergonomically. The anthropometric body dimension data used in product design are in Table 1. Based on Table 1, information is obtained that there are two dimensions needed to make improvements to the work of moving gas cylinders. The two dimensions include elbow height (D4) of 118.17 cm and shoulder width (D17) of 38.75 cm. Figure 2 shows the technical drawing of a trolley stacker product designed to assist workers in transporting gas cylinders from the mode of transportation to the storage area. The goal of this product is to improve high work posture values, reduce the rate of work accidents, and prevent work-related illnesses experienced by workers. The assistive device is based on ergonomic principles using Indonesian anthropometric data, with appropriate allowances taken into account. The height of the trolley handle is 120.17 cm, and the width of the handle is 40.75 cm. These measurements are based on Indonesian anthropometric data. A trolley stacker is a tool used to assist in the Manual Material Handling (MMH) process, which includes holding, lifting, pushing, pulling, carrying, and moving products [27]. Reference [28] conducted at the LPG facility on the activity of moving and lifting gas cylinders recommends the use of trolleys to prevent work-related injuries.

3.4. Work posture with aids

The posture for loading and unloading using a trolley stacker with a mannequin simulation is shown in Figure 3. The figure depicts a worker carrying a gas

cylinder, although the trolley stacker is designed to allow carrying 3-4 gas cylinders. Although there is a decrease in work posture when using a trolley stacker, it is not yet safe enough, and can still cause musculoskeletal disorders (MSDs) for workers. To reduce the risk, workers can stretch their muscles before and during work, as demonstrated by [29] for ikat workers. The use of assistive devices in the study resulted in a slight decrease in work posture, as reported in research [30].

4. Conclusions

The use of assistive devices reduces work posture risk in loading and unloading activities, especially when carrying gas cylinders. Although the risk reduction value is not significant, a trolley can speed up the transfer process of gas cylinders from the vehicle to the storage area. However, the tool designs in this study did not include ergonomic analysis. Further research is needed to develop tools that can minimize work posture risks and reduce work accidents associated with the transportation of gas cylinders.

Declaration statement

Nustin Merdiana Dewantari: **Conceptualization, Methodology, Supervision, Software, Writing - Original Draft.** Aditya Rahadian Fachrur: **Conceptualization, Resources, Writing - Review & Editing, Data curation.** Ade Sri Mariawati: **Conceptualization, Resources, Writing - Review & Editing, Data curation.** Rizky Akbari: **Conceptualization, Resources, Writing - Review & Editing, Data curation.** Muhammad Ferdiansyah: **Resources, Validation, Writing - Review & Editing.** Findi Choerun Annisa: **Resources, Validation, Writing - Review & Editing.**

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The authors report there are no competing interests to declare.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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