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Mapping Potential Musculoskeletal Disorders (MSDs) Based on Ergo-MMH in Manual Material Handling of TBS Loading-Unloading Workers

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Abstract:
Background, The prospect of oil palm plantations is currently rising significantly to become a favourite business. However, the work activities of TBS loading-unloading workers are still performed without paying attention to ergonomic aspects and have the potential for MSDs.
Aim: To map the potential MSDs of TBS loading-unloading workers, serving as a basis for improving the work system.
Methods: The inclusion sample of TBS loading-unloading workers was observed and interviewed using the NBM questionnaire to diagnose potential MSDs resulting from MMH work activities. Ergo-MMH was applied to provide recommendations for improving work system design based on the AT and SHIP approaches.
Results: The primary causes of MSDs are unnatural working attitudes and excessive muscle tension resulting from work systems that are not designed per the limitations of workers. Twelve body parts are directly involved in MMH activities.
Conclusions, Possible MSDs on the back, left and right shoulders, right and left upper arms, right forearm, left and right wrists, left and right hands, and upper and lower neck.
Implication, Ergo-MMH-based mapping of potential MSDs in manual material handling activities of TBS loading-unloading workers for the academic world; research, theory development, and education. For society, public awareness, community development, and social support. For the nation and state, work safety, economic growth, and public health. For the international community, international collaboration, standards development, and technology development.

Keywords: Oil palm, TBS loading-unloading workers, Ergo-MMH, MSDs.

INTRODUCTION

A critical industrial plant that produces cooking oil, industrial oil, biodiesel, and other industrial products is the oil palm (Elaeis). Ogan Komering Ulu (OKU), Ogan Komering Ilir (OKI), Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, South OKU, East OKU, Ogan Ilir, Empat Lawang, Penukal Abab Lematang Ilir (PALI), North Musi Rawas, and Lubuk Linggau are among the nearly all districts and cities in South Sumatra Province that have oil palm plantations. Until now, work activities in oil palm plantations, especially the loading-unloading of Tandan Buah Segar (TBS) are still carried out manually, relying on human labour and the use of tools and work methods that do not pay attention to human limitations (Perdana et al., 2023; Mohamed Rahim et al., 2023; Crowley, 2020). This condition certainly has the potential to cause problems, especially Musculoskeletal Disorders (MSDs), for loading-unloading workers. To date, there is no comprehensive data available, particularly regarding MSDs experienced by palm oil loading and unloading workers as a result of their work. In addition, the unknown level of risk associated with loading and unloading workers' work, as well as other problems such as MSDS complaints, encouraged the author to examine the loading-unloading tools used by these workers and their relationship with MSDS complaints.

The integration of Ergonomics with Manual Material Handling (MMH) in TBS loading-unloading activities involves the transfer of TBS material carried out using tools that utilize human energy. Human ability plays a significant role in supporting the use of tools. The use of tools can provide optimal results, so it is necessary to improve supporting tools according to body posture and the consequences caused to the body. Ergonomics, utilizing the Systemic, Holistic, Interdisciplinary, Participatory (SHIP) and Appropriate Technology (AT) approaches, is applied to provide recommendations for improving the design of the old workstation with a new one that is more ergonomic. In the process of moving TBS material using Hook-T, workers work in various working positions. These working situations will impact the likelihood of experiencing pain in specific body areas. The dimensions and shape of the tojok will affect the effectiveness and comfort of the tojok users. Activities performed to use the tojok include a combination of lifting and pushing activities. Both activities involving the use of this tool will have a significant impact on the risk of Musculoskeletal injuries in certain areas.

Tojok TBS (Hook-T) is a material lifting tool used in plantations, agriculture, industry, and other applications. By definition, a tojok is a hand-propelled lifting device with a T-shaped shaft, used by one worker through a handle. The practicality of this tool has made it one of the most important lifting tools to support production activities. In line with this, many developments have been made to the tojok system. Referring to the conventional Hook-T system, the material loading-unloading process is a tricky part of the activity for workers because it requires much energy, and often workers lose their balance during the loading and unloading process. Based on these conditions, this research aims to recommend improvements to the Hook-T that can reduce the workload for workers during the loading and unloading process, while also enhancing the stability of the loading-unloading process (Smith et al., 2023; Russeng et al., 2021; Hemati et al., 2020). This research aims to identify the potential occurrence of MSDs in MMH activities and recommend solutions using Ergo-MMH, thereby gathering data and information to create an ergonomic and sustainable work system for TBS loading-unloading activities.

LITERATURE REVIEW

Musculoskeletal Complaints

The musculoskeletal system is a system of skeletal muscles or muscles attached to bones, consisting of muscles with transverse fibers whose movement properties can be regulated (voluntarily). Static muscle work occurs in lifting, supporting, pushing, pulling, and unloading activities (arm, shoulder, waist, and back muscles). In contrast, dynamic muscle work occurs in activities such as transporting, pushing, and pulling, which engage the lower muscles. Forced postures during work that last for a long time can cause a burden on the musculoskeletal system and adverse effects on health (Adellian Nugraha & Noeroel Widajati, 2024; Sormunen et al., 2022; Khairani, 2021).

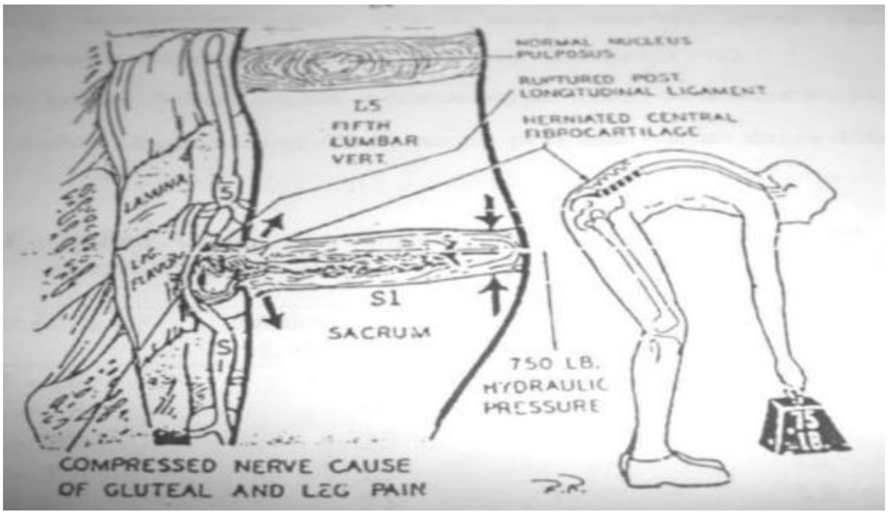
Pains in the skeletal muscles, known as musculoskeletal disorders, can vary in severity from relatively mild to very severe. Long-term exposure of the muscles to static loads can cause damage to the joints, ligaments, and tendons. Typically, problems about this damage are referred to as musculoskeletal injuries or musculoskeletal complaints. Muscle problems can generally be divided into two categories (Zahra & Prastawa, 2023), including: (1) Temporary (reversible) complaints. Muscle complaints that arise when a muscle is subjected to a static load are known as temporary complaints, and they go away as soon as the stimulus is removed. (2) Persistent complaints. Persistent complaints refer to muscle complaints that persist. The muscles continue to hurt even after the workload has been reduced.

According to the study's findings, People most often complain of skeletal muscle issues, which affect the neck, shoulders, arms, hands, fingers, back, waist, and lower extremities. The most common cause of skeletal muscle problems is excessive muscular contraction resulting from excessively demanding workloads that are sustained for extended periods. Mateos-González et al. (2023) state that musculoskeletal symptoms can be caused by several reasons, including: (1) Overstretching of the muscles. Workers who engage in physically demanding tasks, including lifting, pushing, dragging, and holding heavy objects, frequently complain of excessive muscle tension. The reason for this excessive muscle stretching is that the effort required exceeds the muscles' ideal strength. Regular usage of this may increase the likelihood of skeletal injuries and muscular problems. (2) Repeated work activities. Work that must be done repeatedly includes tasks such as hoeing, splitting large wood, lifting, and more.

Muscle complaints arise as a result of the muscles being under constant strain from a lack of relaxation. (3) Unusual Attitudes at Work. Work attitudes that lead bodily components to migrate away from their natural positions, such as uplifted hands, a hunched back, or a raised head, are known as unnatural work attitudes. Skeletal muscle problems are more likely to occur the farther away the body parts are from the body's center of gravity. The characteristics of task demands, work tools, and workstations that are not in line with workers' talents and limitations are typically the cause of this abnormal work attitude. (4) Secondary causal factors for musculoskeletal complaints, namely: a) Pressure. The direct application of force to soft, muscular tissue. For instance, when the hand is required to wield a tool, the tool handle will directly push against the hand's delicate muscular tissue; if this occurs often, it may result in chronic muscle pain, b) Vibration. High-frequency vibration will cause increased muscle contraction. This static contraction leads to poor blood circulation, increased lactic acid buildup, and ultimately, muscle soreness. c) Microclimate. Overexposure to cold temperatures can hinder workers' strength, sensitivity, and agility, making their movements difficult and slow. Additionally, exposure to hot air can also weaken muscles. The difference between environmental temperature and body temperature is too significant, causing some of the body's energy to be utilized in adapting to the environment. Suppose this is not balanced with an adequate energy supply. In that case, Muscle pain may result from a shortage of energy to the muscles, which disrupts blood circulation, reduces oxygen delivery to the muscles, inhibits carbohydrate metabolism, and causes lactic acid accumulation (5). Combination causes. In addition to the factors mentioned above, some experts suggest that individual factors, such as age, gender, smoking habits, physical activity, physical strength, and body size, can also contribute to the occurrence of skeletal muscle complaints.

Weight Limitations that Can Be Lifted

To reduce injuries to the back muscles, such as the waist and back, in lifting and transporting activities, both physiological and psychophysical lifting criteria must be considered. Lifting limits are based on calculations of the risk of injury to the lumbar-5 and sacral-1 discs (L5/S1), so the recommended maximum lifting limit is 3.4 kN as a compressive force on the disc. Injury or pain often occurs in the discus (intervertebral disc) that is between the fourth and fifth discus (L4/L5) or located between the fifth lumbar and 1st sacrum (L5/S1). Figure 1 shows an illustration of the discus L4/L5 and L5/S1.



Source: Bridger (1995)

Figure 1: Location of the sacral lumbar vertebrae (discs L4/L5 and L5/S1). Herniation disorders due to lifting are commonly found at the L5/S1 level.

Physiological lifting limits are determined by considering the average metabolic load of repetitive lifting activities, which can be estimated from the oxygen demand. Work fatigue that occurs due to repetitive lifting activities increases the risk of spine pain. Furthermore, psychophysical lifting limits on the subjective assessment of workers consider the extent to which individuals feel able to lift the maximum load (Bridger, 1995). In general, the individual lifting loads recommended by the International Labor Organisation (ILO) for men and women are examined in Table 1.

Table 1. Recommended Lifting and Transporting Loads for Men and Women

Age (Years)	Maximum for Men (Kg)	Maximum for Women (Kg)
14-16	15	10
16-18	19	12
18-20	23	14
20-35	25	15
35-50	21	13
>50	16	10

Source: Pheasant (1991)

It can be concluded that the method of lifting and transporting, the load lifted and transported, the height of the lifting platform, and the distance of transportation all affect workload, fatigue, and work productivity. Job task factors and work environment can also affect work performance.

METHOD

Research Steps

The research steps are as follows; 1) determining the sample according to the inclusion criteria, 2) letting workers work as usual, 3) observing workers' musculoskletal complaints by interviewing according to the Nordic Body Map Questionnaire, 4) analysing the results of the answers of oil palm loading workers, 5) providing data and information on Musculoskletal complaints to be used as a basis for improving the work system and further research. The site where this study was conducted is the TBS purchase centre in the community of oil palm farmers and TBS Loading-unloading workers in Mekarsari Village, Lalan District, Musi Banyuasin Regency (Muba), South Sumatra Province.

Population and Sample

The population is the entire research subject, namely all labourers or workers at the TBS purchase centre in the community of oil Palm farmers and TBS loaders-unloaders, Mekarsari Village, Lalan District, Musi Banyuasin Regency (Muba), South Sumatra Province. The sample is part of the population studied. However, the research sample conducted was a saturated sample with a population of 12 people, made into research samples that meet the inclusion criteria as follows: 1) age between 21-45 years; 2) in good health (no physical or mental disability); 3) male; 4) have worked as a loading-unloading workers for at least 1 (one) year; and 5) willing to be the object of research until completion.

Nordic Body Map

Muscle fatigue is a physiological phenomenon that can be measured directly with Electromyography (EMG) and heart rate meters to detect the cause of fatigue (Ladriñán-Maestro et al., 2024; Setiawan et al., 2023; Gabriel J. Sanders et al., 2021; Rampichini et al., 2020), while the indirect measurement method is a subjective assessment of workers by questioning and showing body diagrams or questionnaires to determine the location of fatigue or using the Nordic Body Map to diagnose musculoskeletal problems (NBM). The NBM questionnaire was chosen as a measuring tool to assess muscle fatigue in the form of musculoskeletal disorders because this method is easy, inexpensive, and quite reliable (Duha, 2024; Ryu et al., 2023; H. Setiawan & M. Rinamurti, 2020). Implementation in the field was carried out with a simple explanation to labourers. Interpretation of the results of respondents' answers for an average score of 1 is not sick; an average score of 1.1-2 is classified as somewhat sick, an average score of 2.1-3 is classified as sick and an average score of 3.1-4 is classified as very sick.

DISCUSSION

Sample Profile

The total number of labourers at the palm oil buying centre in the community of palm oil farmers and TBS loading-unloading workers in Mekarsari Village, Lalan District, Musi Banyuasin Regency (Muba), South Sumatra Province, was 17 people, of whom five were excluded and 12 labourers were included in the analysis. The samples were all from males and were not ill. The average age of the sample was 29±5.6 years, and they had been working as an oil palm TBS loader-unloader for 2.5±0.5 years.

Subjective Complaints

Based on the answers to the questionnaire of 12 samples who are oil palm farmers in the TBS purchasing centre in the community of oil palm farmers and TBS loading-unloading workers of Mekarsari Village, Lalan District, Musi Banyuasin Regency (Muba), South Sumatra Province. The groups of subjective complaints with no pain are as follows: pain below the waist, discomfort on the soles of the left and right feet, as well as in the buttocks and left and right thighs. Subjective complaints of mild pain fall into the following categories: Left upper arm discomfort, left elbow pain, right elbow pain, left knee pain, right knee pain, left calf pain, right calf pain, left ankle pain, and right ankle pain. The groups of subjective complaints of pain are as follows: Upper neck pain/stiffness, lower neck pain/stiffness, left shoulder pain, right shoulder pain, back pain, right upper arm pain, left forearm pain, right forearm pain, left wrist pain, right wrist pain, left hand pain, and right hand pain. Subjective complaints are listed in Table 2 below.

Table 2. Subjective Complaints Based on the NBM Questionnaire

No.	Subjective Complaints	Average ($\bar{x}$) Before
1.	Pain / stiffness in the upper neck	3.1
2.	Pain / stiffness in the lower neck	3.0
3.	Pain in the left shoulder	3.3
4.	Pain in the right shoulder	3.1
5.	Pain in the left upper arm	2.5
6.	Backache	3.1
7.	Pain in the right upper arm	2.6
8.	Back pain	2.2
9.	Pain below the waist	1.5
10.	Pain in the buttocks	1.5
11.	The left elbow hurts.	2.0
12.	Right elbow pain	1.9
13.	The left forearm hurts	2.9
14.	The right forearm hurts	2.8
15.	The left wrist hurts.	2.9
16.	Pain in the right wrist	2.8
17.	The left hand hurts.	3.5
18.	Right wrist pain	3.4
19.	The left thigh hurts	1.5
20.	The right thigh hurts	1.5
21.	The left knee hurts.	1.6
22.	Right knee pain	1.7
23.	The left calf hurts	1.9
24.	The right calf hurts	1.8
25.	The left ankle hurts.	2.3
26.	Right ankle pain	2.0
27.	Pain in the sole of the left foot	1.5
28.	Pain in the sole of the right foot	1.5

The groups of subjective complaints with no pain are as follows: pain below the waist, discomfort on the soles of the left and right feet, as well as in the buttocks and left and right thighs. Subjective complaints of mild pain fall into the following categories: Left upper arm discomfort, left elbow pain, right elbow pain, left knee pain, right knee pain, left calf pain, right calf pain, left ankle pain, and right ankle pain. The groups of subjective complaints of pain are as follows: soreness and stiffness in the upper neck, lower neck, left shoulder, right shoulder, back, right upper arm, left forearm, right forearm, left wrist, right wrist, left hand, and right hand.

The degree of discomfort caused by MSDs in this study is classified into 4 (four) categories, namely no pain, mild pain, moderate pain, and severe pain. Body parts that do not feel pain are body parts that are not directly involved in the MMH activity of oil palm TBS (Alisha et al., 2021). While subjective complaints, such as feeling pain in certain parts of the body, are supported by the calves, ankles, and elbows. Meanwhile, those classified in the pain category are parts of the body that are directly involved, such as the hands, back, shoulders, and neck (Perdana et al., 2023). In Figure 2 below, the MMH activity of loading and unloading oil palm TBS is shown.

Figure 2. MMH Work Activities for Loading-Unloading Palm Oil TBSs
Source: TBS buying centre in the community of palm oil farmers and TBS loading-unloading workers of Mekarsari Village, Lalan Sub-district, Musi Banyuasin Regency (Muba), South Sumatra Province.

The MMH activity of loading and unloading oil palm TBSs, particularly loading oil palm fruit bunches into the truck, is not designed under the anthropometry of the workers, as the length of the T-hook handle is not optimized. As a result, the back is often bent, the head is raised, and the feet are on tiptoe. This is an unnatural working position because the farther a body part is from the body's center of gravity, the higher the risk of skeletal muscle complaints. The average weight of oil palm fruit bunches ranges from 12 to 55 kg, requiring workers to exert great effort in loading them into the truck. Vosoughi et al. (2024) and Setiawan (2023b) explained that, in addition to heavy loads, the activity of loading oil palm TBSs into trucks involves repetitive motion, typically exceeding eight movements per minute. This excessive muscle stretching occurs because the required exertion exceeds the optimum muscle strength where the Maximum Acceptable Weight of Lift (MAWL) value of Indonesian male workers in the shoulder-reach segment 2 times per minute is 12.3 ± 0.68 kg; 4 times per minute is 11.49 ± 0.59 kg; and 8 times per minute is 10.41 ± 0.68 kg (Ramawisari et al., 2023; Perdana et al., 2023; Setiawan, 2023c). Suppose the activities of labourers loading and unloading oil palm TBSs are compared with the MAWL standards of Indonesian workers. In that case, it becomes clear that these activities fall far short of ergonomic standards. Therefore, it is not surprising that MSDs often occur in these activities.

Recommendations for the Ergo-MMH approach to the work activities of labourers loading-unloading oil palm TBS are as follows; the AT approach to the technical, economic and ergonomic aspects of the T-hook handle tool, will not readily be accepted if it is recommended to use a machine-powered belt conveyor because it is considered that the operational costs are high. The use of labourers will decrease if a belt conveyor machine replaces them. Therefore, the T-hook handle tool should be designed based on the anthropometry of the labourer, and it should also have a soft hand cushion handle on the T and the handle of the stick to prevent pain in the palm. When the labourer holds the handle of the T-hook tool, it is recommended that the working posture during the loading and unloading of oil palm TBS onto the truck is not far from the fulcrum of the body axis (Sugiarto & Perdana, 2024). Socio-cultural aspects enable workers to socialize, as they engage in physical activities together (Setiawan et al., 2025; Rinamurti & Setiawan, 2021). Energy-saving and environmentally friendly aspects still meet the criteria because they do not use machines that have a polluting impact, but the human energy used exceeds the tolerance limits of ergonomics (Setiawan, 2023a; Rasmussen et al., 2020). Overall, it is necessary to design a portable mini belt conveyor for loading and unloading TBS that is effective, comfortable, safe, healthy, and efficient (ECSHE) for both workers and buyers.

Changing the habits and mindset of using the T-hook handle tool to change to a portable mini belt conveyor requires the application of the SHIP approach (Fachri & Muslem, 2020). Systematically solving all problems for workers, but workers still work without the use of physical energy that exceeds the threshold value, a holistic perspective that provides benefits for workers and buyers because ECSHE tools are designed with consideration from multiple disciplines and participatory socialisation and education (Setiawan et al., 2024; Leksono & Wisesa, 2020). Ergonomic loading-unloading tools that are friendly to workers' health are needed. They should be designed to reduce static and repetitive loads on skeletal muscles and minimise the risk of injury (Setiawan, 2022; Soewardi et al., 2020).

CONCLUSION

The average weight of oil palm fruit bunches ranges from 12 to 55 kg, making it difficult for workers to load and unload oil palm TBS into trucks. This excessive muscle strain occurs because the exertion required exceeds the optimum muscle strength, which is the maximum acceptable workload (MAWL) value for Indonesian male workers. A comparison of MMH activities of TBS workers with the MAWL standard for Indonesian workers reveals a significant deviation from ergonomic standards, resulting in a high incidence of Musculoskeletal Disorders (MSDs) in the left forearm, right forearm, left wrist, right wrist, left hand, and right hand.

The primary causes of MSDs are unnatural work attitudes and muscle overstrain stemming from the design of work systems that are not designed under the limitations of workers. The Ergo-MMH recommendation is to design a tool that replaces the T-hook handle with a portable mini belt conveyor, ensuring it is ergonomic and compliant with ECSHE standards for workers and TBS buyers.

IMPLICATION

The implications of Ergo-MMH-based mapping of potential MSDs in manual material handling activities of TBS loading-unloading workers can have a broad impact on various aspects, namely: For the academic world: research, theory development, and education, especially in the field of OHS factors that affect the risk of MSDs in MMH activities in the palm oil agroindustry. For the community, it can increase public awareness, community development, and social support about the risk of MSDs and OHS. For the nation and state, it relates to occupational health and safety (OHS), economic development, and public health. Moreover, for the international community, it relates to international collaboration, standards development, and technology development.

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