Pertanika J. Sci. & Technol. 33 (S1): 23 - 41 (2025)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Testing and Evaluation of Newly Developed Harvesting Basket Among Male Pineapple Harvesters in Johor, Malaysia

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ABSTRACT

This study evaluates a newly developed harvesting basket used in manual pineapple harvesting work in Malaysia, specifically focusing on its impact on physiological workload, body part discomfort, perception of harvesters and risk level of musculoskeletal disorders (MSD). An experimental study was conducted among pineapple harvesters in Muar, Johor. Data from 25 harvesters were collected using questionnaires, including the Borg CR-10 Scale, to assess body part discomfort using traditional rattan and newly developed harvesting baskets. The physiological workload was measured to record heart rates and calculate the workload. The risk level of awkward posture during harvesting tasks was assessed using the Rapid Entire Body Assessment (REBA) tool for both baskets. Descriptive analysis was used to analyze respondents' perceptions, while statistical tests determined performance differences between the two baskets. The results revealed that workers experienced a significant reduction in physiological workload between the use of rattan (6.6 ± 0.9 kJ-min) and prototype baskets (5.0 ± 1.1 kJ-min). Harvesters experienced reduced discomfort when using new harvesting baskets. The postural analysis indicated a decrease in the risk level of awkward posture from high (rattan) to medium (prototype) when harvesting. Most harvesters perceived that the new harvesting basket fulfilled their needs. In conclusion, the newly developed harvesting basket demonstrated the potential to improve work posture, discomfort and physiological workload of pineapple harvesters, thereby

ARTICLE INFO

Article history:
Received: 08 November 2023
Accepted: 05 November 2024
Published: 31 January 2025

DOI: https://doi.org/10.47836/pjst.33.S1.02

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ISSN: 0128-7680
e-ISSN: 2231-8526

reducing the potential of obtaining MSD disease. Adopting ergonomically designed work tools aligns with the MyGAP policy and supports improving workers' health in pineapple harvesting operations.

Keywords: Awkward posture, discomfort, ergonomic tools, physiological workload, pineapple harvesting

INTRODUCTION

The pineapple industry plays a vital role in Malaysia's socio-economic development by improving the livelihoods of smallholder farmers through income generation. A recent study showed that the benefit-cost ratio for the profitability of pineapple farming among 191 smallholder farmers in Johor is 1.72, indicating that pineapple plantations are economically viable and generate profit (Suhaimi & Fatah, 2019). Additionally, it contributes to the overall economic development and supports related economic activities such as packaging, transportation and value-added income-generating opportunities, particularly in Johor. The state of Johor emerged and remained as the largest pineapple producer since 2011 up till today, with an estimated production quantity of 267,913 metric tons (MPIB, 2018) and a total hectare of 8112.06 hectares, followed by Sarawak and Sabah (Suhaimi & Fatah, 2019).

Work in pineapple plantations is characterized by its labor-intensive nature and high physical exertion. Tasks such as harvesting, cultivating, weeding and land preparation involve significant muscle strain and discomfort (Ya'acob et al., 2018). Pineapple plantation workers often encounter posture-related issues, primarily due to the demanding nature of the work and the absence of automation and ergonomic tools (Tamrin & Aumran, 2014). Consequently, these workers face an increased risk of developing musculoskeletal disorders (MSDs) from prolonged symptoms (Rani, Abidin et al., 2016). The prevalence of overall musculoskeletal symptoms (MSS) among pineapple plantation workers was 87.0% and was highest for the lower back (64.8%). The risk for MSDs for pineapple plantation workers may arise from awkward postures, forceful exertion and repetitive movements (Rani, Abidin et al., 2016).

There has been research and reports about mechanized harvesting of fruits to reduce labor intensity and improve harvesting efficiency, including in Malaysia. However, the current market still lacks options for ergonomically designed manual harvesting baskets specifically tailored for pineapple plantations on peat soil (Liu et al., 2022; Mezlan et al., 2019; Rani, Rashid et al., 2016; Yusoff et al., 2014). Rattan fruit harvesting baskets remain the primary equipment used in pineapple harvesting both in small- and large-scale plantations across Johor (Rani, Rashid et al., 2016). Many harvesters modify their rattan baskets to accommodate heavier loads, causing the full-load basket to exceed the safe limit of an ideal lifting load of 23 kg (Kamarudin et al., 2013). However, apart from carrying heavy loads, harvesters are also required to bend their bodies extensively forward during the pineapple unloading process. Specifically, workers need to bend at the waist at an angle of 60° (beyond the safe limit of 45°) to tip the fruits out of the basket due to the basket's design limitations during unloading (Figure 1). The use of raffia rope as the basket strap exacerbates the situation, as it is non-adjustable and does not provide a secure fit, leading to high contact stress on the harvester's shoulder. The flawed design of the existing basket, including inadequate load capacity and a lack of consideration for the tasks at hand (Mezlan et al., 2019), exposes workers to ergonomic risks, especially MSDs, due to awkward postures and repetitive movements during the harvesting process (Rani, Rashid et al., 2016).

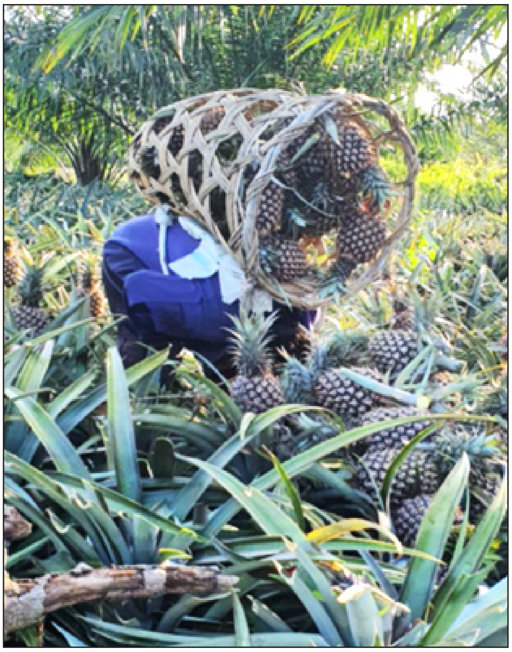


Figure 1. Unloading of pineapples onto the ground by a worker using a rattan pineapple harvesting basket

Given the prevalent challenges faced by pineapple plantation workers in Malaysia, the development of an ergonomically designed harvesting basket is essential to enhance their work conditions. The authors addressed this concern in previous research by creating a novel pineapple harvesting prototype basket (Mezlan et al., 2019). The primary objective of the newly developed basket was to alleviate issues associated with poor posture, contact stress and excessive load burden among workers, thereby reducing the occurrence of reported musculoskeletal symptoms (MSS) over an extended period. The design of the basket incorporated a latch opening into the front side of the rectangular fruit basket, enabling the latch to pivot outward when opened (Mezlan et al., 2019). Adjustable shoulder straps and foam padding were incorporated on one side of the basket, specifically where it comes into contact with the user's back. The new ergonomic basket also implemented a 30% reduction in size (Mansor, 2020). This subsequent study measured several indicators, including physiological parameters such as heart rate, while comparing the use of the rattan basket with the prototype basket, revealing the need for improvements in the basket design because results were not favorable to reduce the probability of workload (average heart rate: 104.9±14.8 beats/minute vs. 108.4±14.7 beats/minute; $p>0.05$) and exertion.

A newer version of the pineapple harvesting basket was developed with the updated findings from the study outcomes in Mansor (2020). There is a need to evaluate and test the newer prototype basket among harvesting workers to provide quantitative data to validate the present design. Perceived musculoskeletal discomfort has been used to indicate early signs of musculoskeletal pain using other studies as a reference (Galinsky et al., 2007;

McLean et al., 2001). Other signs that can predict musculoskeletal pain include bodily discomfort such as soreness, tension, fatigue or tremors (Reenen et al., 2008). Perceived discomfort can be an indicator of early signs of pain arising from short-term biomechanical load on the musculoskeletal system. These short-term effects, coupled with a lack of recovery time, in addition to being recurrent, can lead to musculoskeletal pain (Beek & Frings-Dresen, 1998).

As such, this study aims to evaluate and test a newly developed harvesting basket to assess the potential of its ergonomic design in reducing the discomfort, physiological workload and risk level of awkward posture during unloading tasks experienced by pineapple harvesters. Additionally, the study aims to examine the perceptions of harvesters regarding the new basket to ascertain opinions on satisfaction. The development of the new harvesting basket is expected to improve safety, health, and well-being among agricultural farmers and workers. By promoting the adoption of safe work methods and utilizing enhanced tools and techniques, the new basket is anticipated to facilitate long-term benefits for the workers in terms of their safety and overall welfare.

The academic contributions of this study lie in its comprehensive evaluation of the newly developed pineapple harvesting basket's impact on various critical aspects of manual pineapple harvesting work in Malaysia. This study offers empirical evidence of improvements from a newly developed tool, providing valuable insights into the potential ergonomic benefits of improving the work process. The investigation performed in this study delves into harvester perceptions, serving as an essential step toward understanding user acceptance and facilitating the adoption of ergonomically designed work tools in agricultural practices, which can have implications for improving workers' health and well-being.

MATERIALS AND METHODS

Study Design and Sample Size

This study adopts an experimental design. The research location was purposefully selected as Muar, a district and town in the state of Johor, in the southern part of Peninsular Malaysia, and is known for its pineapple plantation activities.

For the sample size calculation, a formula for sample size estimation with single group mean and standard deviation was used (Kang et al., 2008). Using the study by Mezlan et al. (2019), the means and standard deviations of heart rate measurements were referred to and used for calculations. Sample size estimation was calculated at 12 and with the addition of 10% non-response, a total of 14 sample sizes was required. However, to ensure minimal clinically important effects are observed, the sample size was raised to 25. It is supported by Žunkovič et al. (2023), where the recommended range of 19 to 300 subjects are required to show the minimal clinical effects for heart rate at standard deviations of more than 30%.

Newly Developed Harvesting Basket

The research team developed the new harvesting basket, incorporating ergonomic features to assist harvesters in harvesting tasks (MyIPO Copyright Registration AR2023W02635). It is an upgraded version of the harvesting basket modified from the previous work by the authors (Mezlan et al., 2019). Figure 2 illustrates the design of the new harvesting basket, which was tested in this study. Stainless steel was used as the material to reduce the weight of the basket. The opening latch installed at the bottom of the basket allows for easier unloading of pineapples onto the ground without excessive bending. A single-hand operation on the lever will open the bottom opening and release the fruits, and when the handle to the cable latch is pulled, this closes the bottom opening and locks it back into place. The back structure will evenly distribute the load of the basket on the body, and the adjustable shoulder strap and padded back will provide comfort and reduce contact stress.

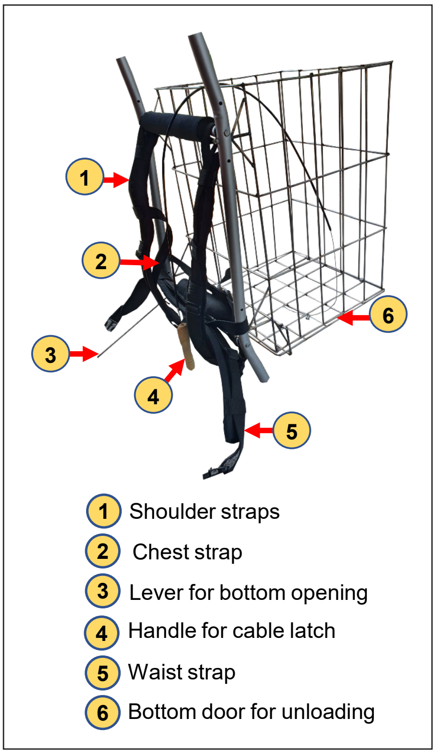


Figure 2. The ISO view of the newly designed pineapple harvesting basket

Approvals and Study Respondents

This experimental study was conducted in December 2021. This study has obtained approval from the Research Ethics Committee at Universiti Putra Malaysia (JKEUPM) with reference number UPM/TNCPI/RMC/JKEUPM/1.4.18.2 (JKEUPM). It has adhered to all necessary ethical guidelines throughout the research process. For this study, approval was obtained from the Malaysian Industrial Pineapple Board (MIPB), and the Muar office helped recruit harvesters registered under the MIPB in the Johor area. A total of 25 pineapple harvesters were recruited as respondents for this study through purposive sampling to conduct testing and evaluation of the traditional harvesting basket, as in Figure 1, while comparing it to the new harvesting basket in Figure 2. The respondents in this study were small-holding pineapple harvesters who were mostly Malaysians.

All harvesting simulation work in this study was carried out at a pineapple collection center in Johor under the MIPB. The area has laterite soil and provides a stable environment for the harvesting simulation exercises. The weather during the data collection period was clear, and the exercises were conducted from morning to before 12 pm only. Inclusion criteria for respondents included male harvesters aged between 18–60 years and engaged in full-time harvesting. Respondents diagnosed with chronic diseases such as heart disease were excluded from the study.

Study Instrumentation and Methods

Questionnaire

A modified questionnaire was prepared in Malay and was administered by the researcher. The questionnaire comprised several sections and was initiated by items on personal, professional or working information and medical history. The last section of the questionnaire was items on perceptions of the new harvesting basket. However, this questionnaire section was provided to the respondents at the end of the loading and unloading simulation exercises.

Borg's CR-10 Scale

Borg's Category Ratio (CR)-10 scale (Borg, 1998) was used in conjunction with a body map from the Nordic questionnaire to enable respondents to visualize the location of the discomfort better to assess perceived discomfort (Kuorinka et al., 1987). Borg's CR-10 uses a rating from 0 for "nothing at all" to 10 for "excruciating" and is a verbally level-anchored ratio scaling.

The use of Borg's CR-10 for assessing perceived discomfort, such as in this study, has been used in other reported ergonomic-related studies elsewhere (Karuppiah et al., 2012; Waongenngarm et al., 2022; Yusof et al., 2022). The primary use of Borg's CR-10 is to determine exertion, chest pain and other kinds of pain, such as muscle pain, breathlessness, and fatigue. It has the advantage of being easier to use for laypersons.

Rapid Entire Body Assessment (REBA)

The Rapid Entire Body Assessment (REBA) tool was utilized. REBA was developed by Hignett and McAtamney (2000) and is a field tool for practitioners to assess changes in postures and movements. It provides a quantitative measure to compare pineapple unloading tasks while using rattan and a new harvesting basket. It is sensitive enough to capture unpredictable working postures in many industries (Cancela et al., 2014).

During the simulation exercise of loading and unloading pineapple fruits, a video of the activity was recorded for each of the respondents. When the authors returned to the laboratory, the video was viewed on a computer and still frames of unloading postures and movements were generated. These were then assessed using the scoring card provided with the tool. The final REBA score determined the risk level associated with the unloading tasks. In addition, a goniometer was used to measure movement angles where needed. REBA exercise represents the biomechanical aspect that is assessed in this study.

Physiological Workload

Physiological parameters used in this study are heart rate measurement and energy expenditure calculation. Heart rate is an indicator of cardiac stress due to physical workload (Bhattacharyya & Chakrabarti, 2012). Although these parameters are not strong indicators linking directly to MSDs, measurements of heart rate and calculation of energy expenditures are practical values to benchmark and compare the efforts to perform the tasks within a short time interval.

The respondents were provided and wore Fitbit Fitness Smartwatches to measure the average heart rate during the task performance of loading and unloading pineapple fruits using both baskets in two different sessions with a 10-minute break in between. Participants were asked to rest under a shaded area but were asked to refrain from smoking to minimize factors that might contribute to variation in heart rate reading. The recorded measurements were downloaded after the fieldwork and were used to calculate energy expenditure (expressed as kJ/min) using Equation 1 (Bhattacharyya & Chakrabarti, 2012; Varghese et al., 1994):

$$0.159 \times \text{Average Heart Rate (beats per minute)} - 8.72 \qquad [1]$$

Flow of Data Collection

Prior to initiating the basket testing simulation, each participant donned a Fitbit Smartwatch to collect data for heart rates during the harvesting procedure. In a single simulation round, the harvesters collected 20 pineapple fruits using the traditional rattan basket while being video recorded. Following a 10-minute rest period, participants responded to the questions to gauge their discomfort levels linked to using the rattan basket.

The simulation process was then replicated utilizing the new harvesting basket, maintaining consistent conditions. In this phase, participants again harvested 20 pineapples using the new basket while video-recorded. Following the physical activity, questions on perceived discomfort were administered to the participants again to assess the use of the new harvesting basket.

Next, a supplementary set of questions pertaining to usage perceptions, which the authors formulated, was provided to the respondents. These supplementary perception items were designed to obtain feedback regarding the new basket's ease of use, comfort and overall practicality. The items in this part of the questionnaire were scored using a Likert scale ranging from 1 (Strongly Disagree) to 10 (Completely Agree) to provide a large enough option to enable differences to be clearly identified. In addition, several open-ended questions were also included to obtain their general perceptions of the design and material of the new basket.

Quality Control

To ensure the questionnaire's validity Borg's CR-10 was translated to Malay from English by a native speaker of Malay and back-translated to English by a Ph.D.-level academic officer who is fluent in Malay and English. The differences in both versions of the questionnaires were identified and only a few translations required amendments, which were then amended.

As evidence of the researchers' competencies, two research team members are recognized as Ergonomically Trained Persons under the Guidelines of Ergonomic Risk Assessment by the Department of Occupational Safety and Health (DOSH, 2017). The researchers trained other team members and cross-checked all assessments to ensure the risk assessments best represented the tasks recorded from video and photos.

The full questionnaire was validated during the pilot-testing phase before the actual data collection, which is intended to ensure respondents understand the questionnaire items and reduce issues with the choice of wording (Sekaran & Bougie, 2016; Stockemer, 2019). A sample of 10% of the total sample size, consisting of male respondents from an educational institution with a similar age range and gender to the intended participants of this study, received the questionnaires. Ambiguous terms identified during the pilot test were amended to ensure respondents clearly understood the questionnaire.

Cronbach's Alpha was employed to assess the questionnaire's reliability. The range of Cronbach's Alpha is from 0 to 1, where a value of 0 indicates no relation and a value of 1 signifies perfect correlation. An acceptable internal consistency is when the value is more than 0.7 (Taber, 2018). In this study, the obtained Cronbach's Alpha value was desirable at 0.78.

Data Analysis

Paired t-tests were conducted to compare the physiological workload and REBA score between the rattan harvesting basket and the new harvesting basket. Wilcoxon signed-rank tests were employed to compare the discomfort level of body parts when using the two different baskets during the harvesting task. The perception of the harvesters towards the new harvesting basket was re-categorized from the 1 to 10 Likert Scale into three groups of Low Agreement (1 to 4), Moderate (5 to 6) and High Agreement (7–10) and was then presented as descriptive analysis.

RESULTS AND DISCUSSION

Sociodemographic and Work Characteristics of Pineapple Harvesters

A total of 25 pineapple harvesters were included in the sample, consisting of Malaysian adult men and non-Malaysian adult men aged between 20 and 60 years, with an average

age of 43.45 ± 11.4 years. The majority of respondents were Malaysian (92%, n=23). Regarding education level, the majority had secondary education (52%, n=13), while 40% (n=10) had primary education. Table 1 presents the summary of the sociodemographic distribution of the pineapple harvesters.

Table 1
Sociodemographic of pineapple harvesters in Muar, Johor (n=25)

Variables	Frequency (n)	%	Mean ± SD
Age (Years)			43.45 ± 11.4
<29	4	16	
30–49	10	40	
>50	11	44	
Education			
Informal education	2	8	
Primary education	10	40	
Secondary education	13	52	
Previous employment			
No	5	20	
Yes	20	80	
Working experiences			
1–10 years	12	48	
11–20 years	8	32	
21–30 years	3	12	
>30 years	2	8	
Working status			
Full time	25	100	
Harvesting Training No	25	100	

Discomfort Level of Pineapple Harvesters Using Different Types of Baskets

Regarding the level of discomfort experienced by the pineapple harvesters using different types of baskets, the results of the Wilcoxon signed-rank test revealed a significant difference in discomfort for all body parts of the respondents. Waist, shoulder, lower back and lower leg areas exhibited significant differences in discomfort levels. Table 2 presents the median distribution of discomfort for the body parts of the respondents using the rattan harvesting basket and the new harvesting basket.

Table 2
Distribution of discomfort score for the body parts of the respondents using the rattan harvesting basket and the new harvesting basket

Variables	Rattan basket	New basket	z-value	p-value*
	Median (IQR)			
Discomfort of all body parts	0.5 (1.00)	0.204 (.00)	-3.760	<0.001*
Waist	0.5 (3.0)	0.00 (.00)	-3.815	<0.001*
Upper back	0.00 (.00)	0.00 (.00)	-1.089	0.276
Middle back	0.00 (.00)	0.00 (.00)	-1.414	0.157
Lower back	1.00 (2.50)	0.00 (.00)	-4.176	<0.001*
Shoulder	3.0 (2.00)	0.5 (0.5)	-4.223	<0.001*
Thighs	0.00(.00)	0.00 (.00)	-1.342	0.180
Lower leg	0.5 (0.50)	0.00 (.00)	-3.690	<0.001*

Significant at $p<0.05$ The Statistical test used was the Wilcoxon Signed Rank Test; Explanation: 0 indicates “nothing at all,” and 10 indicates “excruciating”

The results showed a significant reduction in discomfort levels for various body parts, including the waist, lower back, shoulder and lower leg. The respondents reported less discomfort when using the new harvesting basket compared to the rattan basket. These findings are consistent with previous studies conducted by Mezlan et al. (2019) and Vanderwal et al. (2011), which found reduced discomfort reported by respondents using ergonomically designed tools compared to traditional tools. The most affected body parts while using the rattan basket were the shoulder, waist, and lower back area, which had to support the weight of the load. These results are supported by Mezlan et al. (2019), which showed that the lower back, upper back, and shoulder had the highest mean discomfort scores according to the Borg CR-10 scale.

The results also highlighted positive effects on the comfort of specific body parts with the usage of the new harvesting basket, particularly in the lower back and shoulder area. These improvements can be attributed to the design features of the new basket, such as the bottom opening for unloading, which is key and helps reduce poor posture and excessive bending. Additionally, the adjustable cushioned shoulder strap and padded back of the new basket contribute to both comfort and reduced contact stress on workers' backs (Mezlan et al., 2019).

Body Posture Assessment Comparison for Unloading of Pineapples Using Rattan and New Harvesting Basket

The results indicated that the average Rapid Entire Body Assessment (REBA) score for the rattan harvesting basket was 10.04 ± 0.79, indicating a high-risk level. Conversely, the average REBA score for the new harvesting basket was 4.12 ± 0.82, falling under the medium-risk level. Paired t-test analysis demonstrated significant differences in the REBA scores between the rattan and new harvesting basks, with $p<0.001$. Table 3 illustrates the mean difference in the REBA scores between the two types of baskets, while Table 4 shows sample calculation for the REBA assessment.

The Rapid Entire Body Assessment (REBA) was employed as an evaluation tool in this study to assess the postural risks associated with a specific work task, namely unloading pineapples onto the ground. The risk assessment results indicated that the unloading process using the existing rattan harvesting basket is classified as high risk (64%, n = 16) and very high risk (9%, n = 36). These findings are consistent with Rani, Rashid et al. (2016), who highlighted the hazardous nature of pineapple unloading due to the required work posture and the heavy load of pineapples weighing approximately 50–70 kg. The postural risk analysis reveals that the harvesting process is classified as a very high postural risk, with a REBA score of more than 10, emphasizing the need for improvements.

Comparatively, the risk level of the unloading process is reduced when using the new harvesting basket compared to the rattan basket. The risk level for unloading with the

Table 3
REBA score of awkward posture risk during the unloading process while using rattan basket and new basket (n=25)

Reba Score and Level	Ratan basket n (%)	New basket n (%)	Differences (95%CI)	t-statistics (df)	p-value*
1 (None)	-	-	-	-	-
2–3 (Low)	-	7 (28)	-	-	-
4–7 (Medium)	-	18 (72)	-	-	-
8–10 (High)	16 (64)	-	-	-	-
11+ (Very High)	9 (36)	-	-	-	-
Average REBA score	10.04 (0.79)	4.12 (0.82)	6.1 (5.6, 6.6)	25.47 (24)	<0.001*

Significant at p<0.05 The Statistic test used was a paired t-test for average REBA score only

Table 4
Sample calculation for REBA scoring for unloading of pineapples using rattan basket

Part A: Neck, Trunk and Leg Analysis						Part B: Arm And Wrist Analysis								REBA Final Score	Risk Level
Neck Score	Trunk Score	Leg Score	**POSTURE Score A**	Force / Load Score	**SCORE A**	Upper Arm Score	Lower Arm Score	Wrist Score	**POSTURE Score B**	Coupling Score	**SCORE B**	**SCORE C**	**Activity Score**	12	Very High Risk
2	5	2	7	2	9	4	2	3	7	1	8	11	1		

new harvesting basket is classified as low risk (28%, n=7) and medium risk (72%, n=17). Conversely, unloading using the rattan harvesting basket is associated with high and very high risk levels. This disparity can be attributed to the excessive forward bending at the waist angle of 60° required during unloading with the existing rattan harvesting basket (Rani, Rashid et al., 2016), as illustrated in Figure 1.

The new harvesting basket introduces a novel feature for the unloading process, thereby reducing or eliminating excessive bending during the task. This improvement is attributed to the ergonomic design of the new harvesting basket, which allows fruits to tip out and be unloaded while standing, which contributes to a reduced REBA score. Similar studies have reported comparable findings, where a comparison of postural risks using the Rapid Upper Limb Assessment (RULA) between new ergonomic design tools and existing tools revealed that the RULA score for the new ergonomic design tool was lower than that for the existing tool. The new tool reduced awkward postures to a low-risk score of 3, compared to the existing chisel tool with a score of 7, classified as high risk (Yusoff et al., 2014).

The REBA assessment highlights that the design of the newly developed harvesting basket has the potential to mitigate awkward postures compared to the current harvesting basket (rattan), as suggested by Salleh and Sukadarin (2018). This emphasizes the importance of implementing ergonomic interventions such as tool mechanization to eliminate awkward postures among pineapple plantation workers.

Physiological Workload of Pineapple Harvesters Using Different Types of Baskets

The physiological workload of the respondents was assessed through average heart rate and energy expenditure. Heart rate can be used to indicate cardiac stress due to physical workload, expressed in the calculation using the formula for energy expenditure (Bhattacharyya & Chakrabarti, 2012). The energy expenditure formula is a simple and rapid method to measure occupational workload when performing manual activities. It was developed based on the association between physiological change and subjective feeling of exertion (Varghese et al., 1994). The average heart rate of the respondents using the rattan harvesting basket was 97±6 beats per minute. For the new harvesting basket, the average heart rate of the respondents was lower than that of the rattan basket, measuring 89±7 beats per minute. The average energy expenditure of the respondents while using the new harvesting basket (5.0±1.1 kJ/min) was lower than that of the rattan harvesting basket (6.6±0.9 kJ/min). Paired t-test results indicated a significant difference in heart rate and energy expenditure between respondents using the rattan harvesting basket and the new harvesting basket, with $p<0.001$. Table 5 displays the heart rate and energy expenditure of the harvesters while using the two different types of baskets during the harvesting task.

In this study, the simulation of the harvesting exercise can be considered light compared to the routine work from morning to afternoon. For energy expenditure, the averages obtained in this study denote lower physiological workload because a recent field study showed that energy expenditure for agricultural workers using hoe weeders for 20 minutes

Table 5
The physiological workload of the harvesters while using rattan basket and new harvesting basket (n=25)

Physiological workload	Rattan basket	New basket	Mean (95% CI)	t-test statistics value (df)	P value
	Mean (SD)				
Heart rate	97 (6)	89 (7)	7 (6,9)	10.93 (24)	<0.001*
Energy expenditure (kJ/min)	6.6 (0.9)	5.0 (1.1)	1.18 (0.86, 1.35)	9.32 (24)	<0.001*

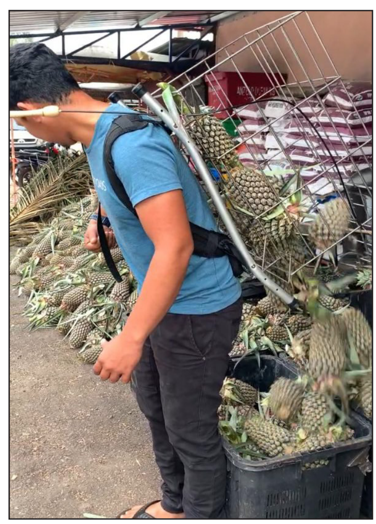
Significant at $p<0.05$ The Statistical test used was a paired t-test. From the average values of heart rate (AHR), energy expenditure (EE) is calculated in the formula as the following EE (Kj-min) = 0.159 × AHR (beats per min.) – 8.72

on a 100 m^2 area ranged between 7.18 and 11.31 kJ/min among workers between the ages of 21 and 36 (Patel & Beg, 2024).

Nevertheless, this does not take away the fact that the use of the new harvesting basket does not eliminate physiological workload because it is still a manual instrument. Because manual harvesting is a selective harvesting approach, only ripe and mature fruit is collected while ensuring the quality of produce and value is retained; it is still often preferred by many small-scaled fruit farmers (Kaur et al., 2023). There are also other reasons for the use of a manual approach, such as to compensate for the peat soil surface, which is soft and uneven, in addition to being a sustainable method that can ensure the employment of local populations (Kaur et al., 2023; Mezlan et al., 2019).

The reduced workload and the reduced heart rate can be linked to the ergonomic features of the new harvesting basket. The new basket, with its features of a rear opening, eliminates excessive bending during unloading by incorporating an opening latch at the rear. It can be depicted in Figure 3, where a respondent unloaded the harvesting baskets. It reduces the ergonomic risks associated with bending, as supported by Mezlan et al. (2019). Additionally, Chung et al. (2001) found that when the trunk of the body was laterally bent and twisted, the average heart rate increased compared to when it was not bent and twisted. Therefore, the opening and unloading features of the newly developed harvesting basket can help reduce the physiological workload of the harvesters.

(a)



(b)

Figure 3. A respondent unloading the load from (a) a rattan harvesting basket while bending more than 45 degrees and (b) a new harvesting basket with a rear opening without bending

Perception of Harvesters Towards the New Harvesting Basket

According to the respondents' perception of the new basket, the majority (92%, n=23) agreed that it met their expectations, and 96% (n=24) believed that it fulfilled the harvesters' needs. A significant majority of respondents, 92% (n=23), expressed that the basket met their expectations. The respondents noted that the basket's lighter weight and comfort make harvesting easier. Table 6 presents the distribution of respondents' perceptions of the new basket.

Table 6
Perceptions of pineapple harvesters towards the new harvesting basket (n=25)

Perception of the new basket	Frequency (n)	(%)
Fulfils expectation		
Medium Agreement	2	8
High Agreement	23	92
Make harvesting easier		
Medium Agreement	1	4
High Agreement	24	96
Feels comfortable		
Medium Agreement	1	4
High Agreement	24	96
Does it fulfill harvester's need		
Medium Agreement	1	4
High Agreement	24	96
Willing to use the new basket?		
Medium Agreement	1	4
High Agreement	24	96
Will reduce harvesting time		
Medium Agreement	2	8
High Agreement	23	92

* Likert-scale re-categorization: Low agreement: 1–3, Medium agreement: 4–6, High agreement: 7–10

When asked about the most important features in a harvesting basket, 64% (n=16) of respondents identified weight and material as crucial factors they look for in a harvesting basket. On the other hand, the opening latch was considered the most interesting and favored feature of the new harvesting basket by 92% of respondents (n=23). It is attributed to the ergonomic design of the basket, which allows for unloading fruits while standing. In contrast, the design of the rattan harvesting basket lacked a bottom opening, requiring workers to bend excessively while unloading fruits onto the ground (Mezlan et al., 2019). Furthermore, the new harvesting basket is perceived as lighter than the rattan harvesting basket, weighing 3kg without a load compared to 5 kg for the rattan basket (Mezlan et al., 2019). Respondents also perceived that the newly added features, such as the adjustable shoulder strap and padded back, provide comfort to harvesters during the harvesting process, making the new basket suitable for extended periods of use (92%, n=23).

However, 60% of respondents believed that the new harvesting basket is incapable of carrying the same load as the rattan harvesting basket. This perception is related to the design and load capacity of the new basket. The new basket is 30% smaller in size compared to the previous rattan harvesting basket, aiming to lower the threshold weight to a safer limit and reduce the burden of heavy loads on the harvesting basket. The new harvesting basket can handle up to 40 kg, but a fully loaded rattan harvesting basket weighs between 50 kg and 70 kg. Since employees carry approximately 500–600 kg daily, this load capacity is considered dangerous (Rani, Rashid et al., 2016).

CONCLUSION

The evaluation showed that the new harvesting basket is linked to the reduction of the physiological workload and discomfort experienced by harvesters compared to the rattan basket. Significant differences were observed in workload and discomfort levels, indicating the potential of the new design to improve posture during harvesting. Respondents expressed satisfaction with the new basket due to its lighter weight, increased comfort and improved usability. On the other hand, social acceptance of the new basket needs to be considered because the new basket is intentionally smaller to reduce the load carrying, which raises a high safety risk during harvesting work. When safety is to be considered to go against the perception of reduced productivity, it may be a barrier for a population of pineapple harvesters to accept and adapt to the use of the new harvesting basket. Further efforts to encourage the use of such harvesting baskets need to be based on existing theories of innovation diffusion (Weinstein et al., 2007).

This study needs to consider some limitations. In the study by Kaur et al. (2023), lower energy expenditures were mostly observed among younger workers, which raises the point about the respondents' age distribution within the present study. This analysis in this study did not differentiate the respondents' age distribution in the energy expenditure calculation. Because half of the workers were from an older age group, the age effects need to also be considered when considering the parameter of energy expenditure. One way to do so is by using the % of maximum heart rate instead of absolute heart rate value (Korshøj et al., 2021).

Generalizing the findings to other pineapple plantations is also not possible as the testing was simulated rather than conducted in real harvesting conditions. The simulated load may differ from actual field conditions in addition to peat soil conditions in Johor plantation areas. Further field testing is necessary to determine the effectiveness and suitability of the new ergonomic basket in actual pineapple plantations, specifically in Johor. In addition, the calculation of the efficiency rate needs to also be included in future research for benchmarking. For example, published literature reported that farmers performing manual harvesting practices for selected fruits can only cover an average of 7.50 ha/hour (Kaur et al., 2023).

The study's findings are valuable and contribute significantly to the scope of enhancing harvesting tools, promoting safety and health and reducing musculoskeletal disorders among agricultural workers in Malaysia. Implementing ergonomic interventions aligns with the Malaysian Good Agricultural Practices (myGAP) certification, which emphasizes seven elements consisting of worker welfare, safety and health apart from environmentally friendly practices as established in the Malaysian Standard Crop Commodity guide (MS 1784:2005) (Department of Agriculture, 2023). This research guides future studies aiming to develop and improve ergonomic tools for agricultural workers. Future research should employ electromyography (EMG) instruments to assess muscle electrical activity, estimate muscle force and analyze muscle fatigue rates in relation to the new basket's design for a more comprehensive and objective assessment.

ACKNOWLEDGMENTS

This project was made possible with the funding provided by the Ministry of Higher Education Malaysia via the Prototype Research Grant Scheme (PRGS 2019-1) with the project number 13050 (reference number PRGS/1/2019/WAB01/UPM/02/2). The project title was "Identification and Evaluation of Design Specification for Prototype Development of Pineapple Harvesting Basket to Potentially Reduce Physiological Load, Musculo-skeletal Symptoms and Discomfort". The project also received support from the Yayasan Inovasi Malaysia and SME Corporation. The authors would also like to give gratitude to the Malaysian Pineapple Industrial Board, Johor for their invaluable support and significant contributions to this project.

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