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ORIGINAL ARTICLE

Development of Smart Fruit Basket for Pineapple Harvesting

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ABSTRACT

Introduction: Pineapple harvesting work contributes to the reporting of musculoskeletal symptoms (MSS) and ergonomic risks. Pineapples are harvested manually in some parts of Malaysia using rattan baskets and workers are exposed to excessive bending, pain and discomfort. This intervention study developed and tested a prototype of an ergonomic harvesting basket to potentially reduce discomfort and physiological workload during a simulation of harvesting activity. **Methods:** The development and testing of improved harvesting basket was performed in laboratory and workshop. The improved basket had adjustable cushion straps, foam back pad and an opening for unloading of fruits. Harvesting was simulated using improved and existing basket by human subjects and questionnaires were used to assess discomfort. Physiological workload was assessed by heart rate and energy expenditure. **Results:** A total of 12 male respondents with average age of 22.4 (2.2) years participated in harvesting simulation. Discomfort as measured in Likert scale (mean (standard deviation) for improved basket 4.13 (6.1) vs existing basket 12.26 (11.2); $p<0.05$) was significantly reduced. Average heart rate (94.13 beats/min vs 89.05 beats/min) and energy expenditure (6 kJ/min vs 5 kJ/min) improved. **Conclusion:** The use of improved basket was linked to reduction of discomfort and overall workload. Improving design of agricultural manual tools may be able to improve health of workers and prevent MSS. Future fabrication of the improved basket using lightweight materials has potential to be expanded into plantation sectors not limited to pineapples in Malaysia and across Asia.

Keywords: Prevention and control, Muscle pain, Musculoskeletal diseases, Discomfort, Intervention

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INTRODUCTION

Work in pineapple fields is labour-intensive, strenuous and consist of highly demanding physiological workload (1). Workers are required to assume awkward posture at many tasks such as cultivating, weeding, harvesting and land preparation that have been shown to be linked with muscle pain and joint discomfort (2). A recent study among workers in a large pineapple plantation company in Southern Malaysia concluded that one-year prevalence of musculoskeletal symptom (MSS) was 87.0% with low back (64.8%), feet/ankle (53.7%) and knee (52.8%) as the most reported body part affected with MSS (3). Compared to palm oil sector, the prevalence in the study was higher than what was previously reported (4).

In Malaysia, work in some pineapple plantations still solely depends on manual tools for planting, weeding, fruit harvesting and cultivating unlike in the palm oil sector even though the pineapple industry started in 1920's (1). Example of a manual tool for pineapple harvesting is rattan fruit harvesting basket that weighs a hefty 5 kg without load. There is no other ergonomically-designed harvesting basket available in the market except for the existing rattan basket. To harvest fruits, the workers will cut the fruit from its stalk with a sharp cleaver and toss it over their shoulder to fall into the rattan basket carried on their back. These baskets are bought from local rattan weavers and its height is often modified to increase loading capacity. A full-load basket is between 50 to 70 kg and generally workers will carry cumulatively up to 500-600 kg in a day. This exceeds the safe limit and ideal lifting load of 23 kg or 51 lbs as suggested by the National Institute Occupational Safety and Health (5).

To unload fruits from the basket onto the ground, workers will need to bend forward at the waist at an angle of 60° (compared to the safe limit of 45°) to tip the fruits out as the design of the basket does not allow other options for unloading process. This task becomes increasingly hazardous on the lumbar area because of the heavy load (of approximately 50-70 kg) carried by the worker. Figure 1 presents a photo of pineapple unloading. Risk factors linked to harvesting task has been shown to lead to the reporting of MSS at the shoulders and feet/ankles (1). These symptoms impact many workforces because the pineapple plantation industry itself is large in Malaysia. In terms of risk assessment, our team previously reported Rapid Upper Limbs Assessment (RULA) results which showed that pineapple workers (91.67%) obtained a score of seven (which is above the action level of 4) for harvesting when using the existing harvesting basket (1). The assessment indicates an immediate change on the work posture was required to avoid serious physical damage due to workers lifting loads of more than 30 kg, awkward body posture and repetitive movement. Another risk assessment study by our team using Rapid Entire Body Assessment (REBA) showed that harvesting was categorized as high and very high risk when using the existing basket because workers obtained a score of 8 to 10 (23.8%) and more than 10 (76.2%) (3).

Figure 1: Unloading of pineapples onto the ground

Evidence of these non-ergonomic working practices indicates the pressing need for an alternative harvesting basket to replace the existing rattan basket used in this trade. Even though work automation is priority in hierarchy of control to reduce occupational risks, it is costly and is not feasible to be performed within a short period of time. Solution in redesigning work tools applying ergonomic principles can be implemented instead.

The existing pineapple harvesting basket are made from rattan which are easily sourced and have superior strength to hold loads. Developing a harvesting basket using alternative materials locally sourced which is as superior in strength as the rattan is possible. The existing harvesting basket also does not consider human interface in its design (such as tapering at the side surface where it meets the back) and the straps/harness that supports the lumbar and the shoulder area to reduce contact stress on the body. In addition, the design of the basket itself is flawed because of its unsafe load capacity and it does not take into consideration of the tasks at hand, such as the unloading of fruits.

All the issues explained highlights the need for the identification of an ergonomic pineapple harvesting basket, followed by its evaluation to identify its potential to reduce the safety and health risks associated with the harvesting task while maintaining the productivity of the users. This study aims to develop and test a prototype of ergonomic harvesting basket to improve the existing basket used for pineapple harvesting activities. This new basket is expected to reduce the physiological workload and discomfort associated with harvesting task.

MATERIALS AND METHODS

This study developed a prototype of an ergonomic pineapple harvesting basket to replace the existing rattan basket used in pineapple plantations. This is an intervention study in which the prototype developed was tested in harvesting simulation activities. This study was conducted between October 2016 to April 2017. Designing and simulation test of the basket was performed at the Occupational Safety and Health Laboratory, Universiti Putra Malaysia. The fabrication of the prototype took place in an engineering workshop. This study received ethical approval from institutional ethics review board of Universiti Putra Malaysia.

Development of a new harvesting basket

Two previous studies were referred to identify and examine the risk factors involved in harvesting tasks (1, 3). The new harvesting basket was expected to reduce 1) awkward position, 2) contact stress to body parts of workers and 3) reduce the heavy load burden experienced by the workers to ultimately reduce the reported MSS in the long run. As such, the identification of the design specification of a new pineapple harvesting basket were made considering these three criteria. The design criteria consisted of the following:

- A latch opening connected to the front side of the rectangular fruits basket to tip out when latch is opened. The latch will be operated by a mechanical button on the side of the basket. This will eliminate awkward position.
- A pair of adjustable shoulder strap attached at one side of the basket and a foam padding on one side of the basket where it meets the user's back. This will eliminate contact stress.
- A 30% reduction in size to reduce the threshold weight to a safer limit. This will reduce the heavy load burden.

Upon the identification of these design specification, the prototype of the basket was developed.

Study method and tools

Harvesting simulations were performed in laboratory setting to test work performance using the existing rattan harvesting basket and the newly developed prototype of ergonomic harvesting basket. Two measurement parameters were collected during the simulation test namely the measurement of 1) physiological workload and 2) reported muscle discomfort (Likert scale). The instrumentation that was used to collect these two parameters was a Polar Heart Rate Monitor S610i and a structured questionnaire.

Physiological workload

To assess physiological workload, several parameters were measured. The working heart rate (every 1 minute) while participants were performing harvesting tasks was measured using heart rate monitor. In this study, heart rate is used as a gauge for cardiac stress that arises from physical workload. Using the mean calculation of heart rate, energy expenditure was obtained by means of the calculation using the following formula: Energy Expenditure (Kj-min) = 0.159 x Average Heart Rate (beats per min.) – 8.72. Physiological workload measurements also comprised of peak heart rate values (6, 7).

Questionnaire

The structured questionnaire was provided in Malay and English language and was pre-tested to ensure its validity. The questionnaire consisted of three parts. Part A consisted of items on background information while Part B inquired health information. Part C included items on the response to discomfort when using both baskets and was based on Borg's CR-10 (8).

Simulation of pineapple harvesting

For the purpose of testing the developed prototype, a simulation activity of pineapple harvesting was conducted. The simulation activity involved a group of participants who performed the harvesting activity using both harvesting baskets; firstly using the existing basket and then using the newly developed prototype harvesting basket. Participants of the simulation test consisted of a group of 18-25 years old males, recruited from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. The sampling method used to recruit participants was convenience sampling method where the recruitment process took place in the college itself. The inclusion criteria was that the recruited males were healthy (had no history of chronic disease and no disability), had normal Body Mass Index (BMI) and had no history of being diagnosed with musculoskeletal disorders (MSD). The exclusion criteria required those who were active smokers to be excluded from the study. The selection of participants in this study follows the characteristics of actual pineapple harvesters found in our previous study (3) to a large degree. A questionnaire was distributed to collect information of the respondents at the invitation and recruitment stage to determine whether the respondents fulfilled the criteria needed. After agreeing to a set time and date for the simulation exercise, the laboratory simulation was initiated. Before the simulation was conducted, a short briefing session was given to ensure participants had clear instructions. After the simulation, the respondents were asked to rate their discomfort.

The respondents used the existing harvesting basket for the first experiment and the new harvesting basket for the second experiment. The second experiment was done after 1 hour of rest. For every experiment, the simulation was repeated five times for both baskets. A simulation took about one minute to complete so when the simulation was repeated for five times, it took about five minutes to complete the simulation for every basket. The measurements of working heart rate were compared after experiment was completed. Respondents wore Polar heart rate monitor at their wrist while the transmitter of the monitor was worn under the chest while the connector was placed at the middle. The pineapple simulation used 10 pineapple fruits that weighted about 1 kg per fruit. Therefore, the total fruits used during the simulation were 10 kg.

Statistical Analysis

The data obtained was analysed using IBM SPSS (Statistical Package for the Social Sciences) version 22. The demographic information of the respondents and the respondents' perception when using new basket were analysed using descriptive analysis. The average working heart rate and discomfort level for both knapsack baskets were analysed using paired t-test. From the average values of heart rate (AHR), energy expenditure (EE) was calculated.

RESULTS

The response rate was 48% (N=12). All respondents in this study were Malaysian male with an average (standard deviation) age of 22.4 (2.2) years old. The respondents had average weight of 68.0 (15.4) kg and average height of 1.7 (0.1) m. The respondents had average BMI of 23.8 (5.0). All respondents received education up to university level. The information on socio-demographic background of the respondents are presented in Table I.

New basket prototype

The main material used for the new basket was iron. Iron was used because it could be welded to make the opening for the basket to prevent excessive bending of more than 60° during unloading of fruits. The basket was designed in a rectangular trapezoid to replace the cone shape of the existing basket that gave contact stress to the back area of the body.

Modified shoulder straps

Adjustable shoulder polyester straps were used to replace the raffia strap used for the existing basket. The polyester strap was used due to higher durability. The adjustable straps are also suited with anthropometric dimensions. The strap had wider width and is covered by a padding to provide suspension and to minimize

Table I. Frequency distribution of sociodemographic characteristics of respondents in simulation test (n=12)

Variables		Sociodemographic		Mean (SD)
		Frequency	Percent (%)	
Age (Years)	20	1	8.3	
	21	6	50.0	
	23	2	16.7	22.4 (2.2)
	25	1	8.3	
	26	2	16.7	
Weight (kg)				68.0 (15.4)
Height (m)				1.7 (0.1)
BMI	Normal	9	75.0	
	Overweight	1	8.3	23.8 (5.0)
	Obese	2	16.7	
Marital status	Single	12	100.0	
	Married			
	Divorced			
Educational level	Primary			
	Secondary			
	College			
	University	12	100.0	

n= Frequency SD= Standard deviation BMI= Body mass index

the impact of sudden downward forces. The straps help reduces MSS by evenly distributing weight carried by workers. A soft padding that comes with the shoulder straps helps to reduce contact stress. All this mechanism helped to reduce level of discomfort among workers.

Opening for unloading

This new knapsack basket had a latched opening for unloading at the rear of the basket. The opening reduces physiological workload because it allows unloading of fruits while standing. The workers do not need to bend to unload fruits from the basket onto the ground. This will eliminate the ergonomic risk factors of excessive bending during harvesting thus helped in reducing the MSS among workers.

Padded back/ foam padding

The basket had a padded back to reduce contact stress on workers' back. The padded back was made of foam, a thin plank and PVC leather. A small and light plank was used to support the back of knapsack baskets' users. Then, foam was put to give comfort to back of users. The foam was wrapped with PVC leather because this material is lighter than real leather, easy to clean and resist fading. The foam padding was used to replace gunnysack used by workers to cover their back from pineapples' barbs. The foam helped to reduce barbs contact with back of workers. Figure 2 presents the drawing of the newly developed harvesting basket in ISO view.

Evaluation of discomfort among respondents using different types of baskets

Result for overall distribution of discomfort among

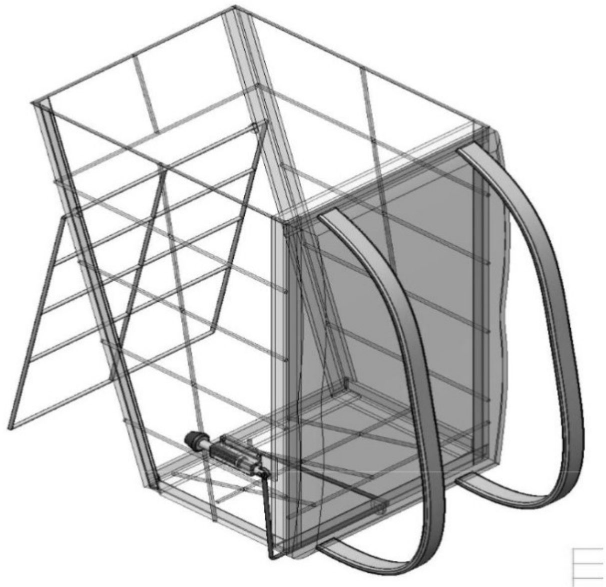

Figure 2: ISO view of newly developed harvesting basket

respondents when using different types of baskets was tabulated in Table II. The result showed that there was a significant different (p=0.012) when using existing and improved baskets. Discomfort for every parts of body of respondents using different types of baskets showed that there were significant differences for neck (p=0.032), shoulder (p=0.004), upper back (p=0.041) and hips (p=0.048) area.

Physiological workload among respondents using different types of baskets

From Table III, overall distribution of heart rate of respondents for five rounds showed a significant

Table II: Distribution of discomfort for all parts of body of respondents using existing and improved baskets during simulation test (n=12)

Variable	Mean (SD)		Mean difference (95%CI)	t-statistics (df)	p-value*
	Existing basket	Improved basket			
Discomfort all body parts	12.26 (11.2)	4.13 (6.1)	8.13 (2.13, 14.12)	2.98 (11)	0.012*
Neck	1.78 (2.1)	0.49 (0.8)	1.28 (-0.21, 0.89)	2.45 (11)	0.032*
Shoulder	2.33 (1.8)	0.92 (0.9)	1.42 (0.56, 2.27)	3.64 (11)	0.004*
Elbow	0.98 (1.6)	0.11 (0.1)	0.88 (-0.17, 1.92)	1.85 (11)	0.091
Upper back	2.04 (1.9)	0.91 (1.9)	1.13 (0.06, 2.21)	2.32 (11)	0.041*
Lower back	1.76 (1.7)	0.94 (2.0)	0.82 (-0.24, 1.87)	1.70 (11)	0.117
Wrist/ hands	1.42 (2.3)	0.51 (0.8)	0.91 (-0.46, 2.28)	1.46 (11)	0.172
Hips/ thighs/ buttocks	0.81(1.2)	0.13 (0.2)	0.68 (0.01, 1.36)	2.23 (11)	0.048*
Knees	0.48 (1.0)	0.08 (0.2)	0.39 (-0.26, 1.04)	1.33 (11)	0.210
Ankles & feet	0.67 (1.5)	0.05 (0.1)	0.62 (-0.33, 1.57)	1.43 (11)	0.181

*Significant at p<0.05 * Statistic test used was paired t-test difference when using existing and improved baskets (p=0.021). From Table IV, working heart rate for respondents were significantly higher at third round (p=0.036), fourth round (p=0.001) and fifth round (p<0.001) of experiments when using existing basket compared to new basket. Table V showed the overall distribution of energy expenditure of respondents using existing and improved baskets. From the table, it was reported that there were significant differences between energy expenditure for existing and improved baskets (p=0.021).

Table III: Overall distribution of heart rate of respondents using existing and improved baskets during simulation test (n=12)

Variable	Mean (SD)		Mean difference (95%CI)	t-statistics (df)	p-value*
	Existing basket	Improved basket			
Average heart rate for 5 rounds	94.13 (9.9)	89.05 (13.3)	5.08 (0.94, 9.22)	2.70 (11)	0.021*

*Significant at p<0.05 * Statistic test used was paired t-test

Table IV: Distribution of heart rate of respondents using existing and improved baskets according to rounds of simulation test (n=12)

Variable	Mean (SD)		Mean difference (95%CI)	t-statistics (df)	p-value*
	Existing basket	Improved basket			
Heart rate 1st round	89.25 (9.6)	86.50 (11.3)	2.75 (-3.48, 8.98)	0.97 (11)	0.352
Heart rate 2nd round	92.25 (10.4)	91.83 (13.9)	0.42 (-6.07, 6.90)	0.14 (11)	0.890
Heart rate 3rd round	94.75 (10.2)	89.25 (13.8)	5.50 (0.43, 10.57)	2.39 (11)	0.036*
Heart rate 4th round	97.33 (11.8)	88.67 (14.7)	8.67 (4.32, 13.01)	4.39 (11)	0.001*
Heart rate 5th round	97.08 (12.3)	89.00 (14.9)	8.08 (4.46, 11.70)	4.92 (11)	0.001*

*Significant at p<0.05 * Statistic test used was paired t-test

Table V. Overall distribution of energy expenditure of respondents using existing and improved baskets during simulation test (n=12)

Variable	Mean (SD)		Mean difference (95%CI)	t-statistics (df)	p-value*
	Existing basket	Improved basket			
Energy expenditure for 5 rounds	6.0 (1.6)	5.0 (2.1)	0.81 (0.15, 1.47)	2.70 (11)	0.021*

*Significant at p<0.05 * Statistic test used was paired t-test
From the average values of heart rate (AHR), energy expenditure (EE) was calculated with the formulae [6; 7] as the following: EE (Kj-min) = 0.159 x AHR (beats per min.) – 8.72

DISCUSSION

Malaysia is one of the many producers of pineapples in the world with plantation areas of 10,847 hectares yielding an estimated production of 272,570 metric tons in 2015 which translates to a value of RM 348.2 million (9). Pineapple is one of the selected non-seasonal tropical fruits included in the Economic Transformation Programme (ETP) Economic Entry Point 7 under agriculture sector in the Malaysian National Key Economic Areas (NKEA) since 2011 (10, 11). Despite its inclusion in the ETP, work in pineapple plantation still solely depends on manual tools for planting, weeding, fruit harvesting and cultivating of pineapples unlike in the palm oil sector (1).

In pineapple plantations, it is common for workers to perform one type of specific tasks, as such harvesters will continuously only perform harvesting tasks for the duration of their employment. Workers will generally perform work for four to five hours in a day and unsafe working practices occurs daily (six days in a week) (3). In a work task that is repeated, similar groups of muscles are triggered which in turn forces the tissues to go beyond its internal tolerance when done for a prolonged period and without enough rest (12). From a previous study, it is common for pineapple plantation workers to have a history of tenure of more than 10 years and consist mostly of local farmers (3). As most pineapple workers were native to the areas of study; workers were likely to continue their present job despite the exerting work. This exposes pineapple workers to ergonomic risk factors on an on going basis.

There have been no studies published in Malaysia regarding the development of a new and improved harvesting basket for pineapple plantation sector. In terms of work tools for palm oil, one study developed an ergonomic chisel (cutting tool) for harvesting based on user-centred design approach (13). The study reported the potential of improved work performance and reduced awkward body posture as compared to the use of existing tools. Outside of Malaysia, one study reported the results of testing a new tea harvesting basket in India. The modified tea harvesting basket were designed using substituted materials from cane instead of bamboo and consisted of improved ergonomic specification which allows the consideration of the average body sizes of female tea harvesters (7). From the study. it was found that significant exertion and physiological workload together with MSS was reduced with the use of the improved basket.

Conceptual design of new harvesting basket

Pineapple harvesters do not have the option to use wheelbarrows at pineapple fields because of the unsuitable structure of the soft peat soil (3). When wheelbarrows are used, instead of pushing, the workers had to pull the wheelbarrow making the work more strenuous. More physiological workload was needed because of the uneven soil thus, the only choice that the workers had was to use the rattan basket to collect pineapple fruits. However, the existing basket did not suit to the workers' comfort ability due to improper design structure. Usage of the rattan basket force the workers to excessively bend to unload fruits onto the ground because the basket did not have any opening at its bottom (3). In addition, the rattan basket did not have proper strap and the workers tend to make their own strap using raffia string. Raffia string has a narrow width thus exposing workers to contact stress at their shoulders and upper limbs. Raffia string is not adjustable and do not fit with workers' anthropometric dimensions. The workers also added a gunnysack at their back because they wanted to cover their back from pineapple's barbs that added to the existing load.

Therefore, a new basket was designed to overcome the problem of the existing basket. This new basket used iron as the main material to develop the basket because this iron could be welded to make an opening for the basket for pineapple loading. Other materials such as wire mesh, aluminium, nylon streamers and bamboo were considered however none of these materials could be used because the basket had to have an opening which could be welded. This study wanted to eliminate the excessive bending during pineapple unloading so iron was the most suitable material compared to others. Polyester was used to make the adjustable strap of the new basket because polyester was used in harness manufacturing and suitable for anthropometric dimensions of the workers. This was due to the strap had wider width thus reduced contact stress on the workers' shoulder and upper limbs. Cushion was also added to the polyester strap and placed on the workers' shoulder. This additional cushion was used to absorb sudden force and reduce the strain on shoulder during the collection of fruits. For the padded back, a foaming pad was used and covered with PVC polyester to replace the gunnysack used for existing basket. The foaming pad gave comfort to workers while the PVC polyester was waterproof, anti-abrasion and anti-fading.

The new basket was designed as rectangular trapezoid because this design wanted to eliminate the contact stress to back of workers and ease the pineapple collection. The back of the new basket was designed as rectangular to get the straight structure so that the workers' back will not be in contact stress with the structure of the basket. In addition, the straight structure also designed to ease the installation of the backrest to replace the gunnysack used by workers to prevent from pineapples' barbs. This was due to the fact that the existing basket was in cylindrical shape making the workers' back to be in contact stress with the basket during the pineapple collection. On the other hand, the trapezoid structure of the new basket was designed to ease the pineapple collection. This is because workers toss fruits into the basket and if the structure of the new basket was small; the fruits will not get into the basket but ended up on the ground. Therefore, the structure of the basket was designed to be wider and longer to overcome the problem and the trapezoid design was suitable to solve the issue. On the other hand, the new basket had an opening for unloading at the back thus excessive bending during the unloading of the fruits onto the ground is eliminated. For the unloading, the workers only had to press on a button that was located at the right side of the basket, and the latch of the basket will be open to unload fruits. The opening could be latched into locking position for the next cycle of harvesting.

Physiological workload among respondents using different types of baskets

In this study, the respondents had a lower average heart rate when using the new basket compared to the existing basket, as the respondents do not need to bend excessively to unload fruits. This finding was supported by one study (14) that reported increased average heart rate count when trunk of the body was laterally bent and twisted, as compared to the trunk posture without such motion (98.76 vs. 94.66 beats/min).

The average heart rate of the respondents when using existing basket increased significantly during each carrying trip. This finding was supported by another study that stated the mean heart rates of workers carrying soft drink beverages increased to 164 and 156 beats/min, respectively, as the number of trips increased (15). The average heart rate (94.13 beats/min) when using improved basket was considered as a very light physiological workload while when using the existing basket, the average heart rate (89.05 beats/min) was considered light in this study. This finding was supported by Borah and Kalita (16) that stated the physiological workload will be considered as very light if the heart rate was 90 beats/min and below while considered as light physiological workload if the heart rate was 91 to 105 beats/min. Vanderwal and colleagues (17) reported that maximum heart rate of subjects lowered to 5% when using the new short hoe, compared to the traditional hoe. This statement proved that usage of improved basket was better than existing basket due to significant reduction of the physiological workload.

The energy expenditure in this study showed that when using new basket, the energy expenditure needed was lower than the energy expenditure when using existing basket. This finding was supported with a study by (7) that designed a new basket for tea-leaf plucking. The finding of the tea-leaf study showed that, the energy expenditure needed for new basket (6.57 kJ/min) was lower than the energy expenditure when using existing basket (7.07 kJ/min). The tea-leaf workers considered the plucking activity as light activity when using the new basket but moderately heavy activity when using existing basket.

Borah and Kalita (16) stated that the energy expenditure 5 kJ/min and below was considered as "very light physiological workload" while the energy expenditure of 5.1 to 7.5 kJ/min was considered as "light physiological workload". That study supported the findings of this study that the improved basket is better as the energy expenditure when using the improved basket (5 kJ/min) was considered as "very light physiological workload" while energy expenditure when using the existing basket (6 kJ/min) was considered as "light physiological workload".

Discomfort among respondents using existing and improved baskets

This study reported that the discomfort of respondents reduced when using the improved basket compared to the existing basket. This may be due to additional design criteria of the improved basket to ease the process of harvesting of pineapple. There was significant reduction of discomfort of neck, shoulder, upper back, hips, thighs and buttocks of the respondents when using the improved basket compared to the existing basket. That finding was supported by (17) that demonstrated an extended hoe handle decreases back pain as the workers are able to perform work in a standing manner when compared to a hoe which is shorter. Better working posture reduced incidences of back pain.

The study by Md Yusoff and colleagues (13) on the design of a new chisel for oil palm fruit harvesting showed a significant reduction in energy use at the right Brachioradialis and left Deltoid muscle. The right Biceps showed almost significant muscle activity reduction when the new tool was used. The trend indicated that the newly proposed chisel generated lower muscle activities compared to the current chisel. Similarly, the study by Vanderwal and colleagues (17) reported that using a longer hoe reduced discomfort of subjects in the lower back, hips and legs and near miss compared to the use of traditional or shorter hoe. Usage of the longer hoe mitigates discomfort of the upper body part. Application of longer hoe allowed respondents to perform task with a better posture compared to using the existing hoe. Besides that, the finding of the present study was supported by Ojha and Kwatra, (18) that reported new rice trans-planters are able to mitigate work by 36.1% and 69.8% within the context of physiological cost/ha when the differences are based on the old method of work. The equipment used avoid the awkward posture adopted when performing work using the old method.

Among the limitations of this study was the selection bias as the respondents recruited were not the actual pineapple plantation workers that experienced the MSS due to harvesting process. Due to the fact that this study did not involve actual pineapple workers, the amount of load carried also did not resembled the actual load carried by the workers using the existing basket where a full-load basket may be up to 50 kg. Thus, the actual discomfort and physiological workload of workers when using the new basket may not be fully accurate. Another point that needs to be emphasised is that although this study selected only males and respondents who had normal BMI, only 30% of actual plantation workers were within the age range of 18-30 years old as reported in our previous study (3). As such, the study findings should not be generalised to the whole harvesting populations in Malaysia.

Within the context of the study design, this study did not involve the use of control group due to time limitation. The development of the prototype took 3 months' time and the time allocated for the harvesting simulation was limited. To further improve the design of the study, it is recommended that a control group to be added for future research. It is also suggested that the design of the harvesting simulation be enhanced with the inclusion of randomisation element. In the present study, the respondents uses the existing basket for the first part of the simulation and for the second part, the respondents uses the newly designed prototype. Is it suggested that for future study, the grouping are divided into three groups, where the first group of the respondents uses the newly developed prototype for the first part of the simulation and then continues with the existing basket; the second group to only use the newly designed prototype and the third group to only use the existing basket. This is to determine whether the findings remain similar or will there be differences in the results.

The testing of the new basket did not use the same assessment done by previous study that was RULA and REBA to the actual workers. This should be done to compare the posture of workers when using existing and new basket to identify any other improvement to be done to the new basket. However, due to money constraint, the assessment using RULA and REBA could not be done to the actual workers.

In terms of the developed prototype, improvement and modification should also be done to the new basket as sometimes the latch of the basket might not be opened and stuck due to force exerted on the basket or the latch opened by itself during the harvesting process making the fruits to fall off along the passage. The design criteria of the latch were a good idea in preventing the excessive bending during unloading of fruits, but improvement should be done to ease the process. The addition of a hip belt may also be useful to redistribute weight from the upper back, neck and shoulders to the hips (19).

CONCLUSION

This study concluded that the newly designed basket might be better than the existing basket because there was a significant association with the reduction of physiological workload of the respondents using the improved basket compared to existing basket. The energy expenditure needed by respondents using improved basket was also less than the energy expenditure needed for the existing basket. The use of the improved basket was linked to reduced discomfort of body parts and gives comfort while work activities are performed which in its entirety may also help in reducing MSS. Thus, this could increase the productivity of the workers if the improved basket is being used in a long run to replace the existing rattan harvesting basket.

Development of ergonomically designed harvesting tool in this field not only has the ability to enhance the safety and health of workers, but the use of ergonomic inventions will positively add in the fulfilment of criteria required by the Malaysian Good Agricultural Practice (myGAP) certification scheme structured by the Department of Agriculture, Malaysia (20). The myGAP certification is a recognition scheme for plantations that practices good agricultural methods that among others are environmental friendly and protects the welfare, safety and health of workers apart from producing quality products for consumption.

Within the context of pineapple industry, myGAP is a requirement for smallholding owners to qualify for agricultural incentives provided by the government via Malaysian Pineapple Industry Board (MPIB). The incentives are among the efforts taken to encourage the economic growth of pineapple industry in Malaysia. As such, this ergonomically-designed pineapple harvesting basket has the potential to benefit multiple stakeholders in this field and also other related agricultural fields. Future fabrication of the improved basket using lightweight materials has potential to be expanded into plantation sectors not limited to pineapples in Malaysia and across Asia.

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