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Original Article

Oil Palm Workers: Designing Ergonomics Harvesting Tool Using User Centered Design Approach to Reducing Awkward Body Posture by Catia Simulation

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Abstract

Background: The aim of this study is to develop a new ergonomics chisel based on user centered design approach and to evaluate the effectiveness for reducing awkward posture using CATIA software for simulation analysis.

Methods: Respondents were selected using purposive sampling – age 18 – 49 years old, men, experience using chisel (>1 month). A set of questionnaire were used to interview workers while postural risks were determined using Rapid Upper Limb Assessment (RULA). Selected anthropometric parameters were taken and user centered design concept were applied to determine mismatch and to facilitate design process. CATIA software was used to integrate the results of postural analysis and anthropometric measurement using 3D modeling.

Results: A total of 273 male harvesters participated in this study. The result shows 5.2% of the chisels' length of handles matches with the respondents whereas none (100%) of the chisels' circumference of handle matches with respondents' internal grip diameter. Tool-chisel usage, majority of harvester bend forward while harvesting (96.7%) and most of workers having blister (83.2%), redness (85.3%) and numbness (65.9%) during harvesting. RULA simulation analysis showed the score action level for new design is 3(further investigated need and changes may be required) compared to existing tool are in action score 7(investigated and changes required immediately).

Conclusions: The study showed that the design of new harvesting tool has the potential to reduce awkward body posture during harvesting activities as compared to existing tools.

Keywords: Harvesting tool, Awkward posture, User centered design, CATIA simulation

Introduction

The rapid expansion in oil palm cultivation has resulted in a corresponding increase in palm oil production from less than 100 000 tons in 1960 to 11.8 million tons in 2001(1). In 2008, Malaysia recorded production of 17.7 million tons of crude palm oil and is the second largest producer of palm oil in the world. In order to maintain and increase production capacity, harvesting of oil palm fruit should be sustainable. Nevertheless, many harvesting machines had been developed by industrial and agricultural machine manufacturer for harvesting palm fruit bunches by local manufactures in the past 20 years, manual tools is still widely use considering the cost effectiveness of chisel and sickle as compared to costly and limited application of mechanization in harvesting oil palm fruits. Among factors, which should be taken into consideration when developing harvesting tool such as ground pressure, manual workability, technique of harvesting, health consideration, and the utmost important aspect were the safety to the operator (2). Harvesting of palm oil fruit is physically demanding, arduous and require extremely large amount of energy in performing the tasks (3). Therefore, proper matching of machine/equipment requirements with the human capabilities or the man–machine system is necessary for optimum performance.

For efficient design/design refinement of machinery/equipment, it is necessary to follow the guidelines and principles of ergonomics, which provide an orientation towards physiological and psychological needs of operators. The design of equipment is always a compromise between the operator biological needs, which are determined by the ergonomics guidelines, and physical requirements of the machinery/equipment (4-7).

Poor ergonomics hand tool design is well-known factor contributing to biomechanical stresses and increasing the risk of cumulative trauma and carpal tunnel syndrome disorders in particular the risk factor of injuries and MSDs in long term (5). An overall agricultural injury incidence rate of 1.25/1000 workers/year in India and an estimated 77.6% of all incidents were due to farm machinery, 11.8% were due to hand tools, and the remaining 10.6% were due to other factors (8).

To date, there has not been yet any research, which focuses on the development of ergonomics hand tools for palm oil harvester based on user centered design approach integrated with OSH. Previous researchers were more focused into method in improving the productivity and lack of attention to tools itself such as ergonomics design accordingly into user perspective, health effect (such as musculoskeletal disorders) and awkward posture while harvesting.

In this study, only chisel was use for cutting frond and harvesting fresh fruit bunch (FFB) because the height of the palm trees namely still short (< 5.5 m). Therefore, using chisel at 5 meter high, required workers to bend their body and generate extreme force to harvest the bunch or cutting the frond as shown in Fig. 1. At this level, workers has the potential risk to develop muscular pain at various body part due to frequent awkward posture such as bending, hand position, hyper extended hand or wrist and extreme hand and wrist postures and high work demand -forceful exertion (9).

Fig. 1: Harvesting activities of free fruit bunch from oil palm tree

Hand tools information

Hand anthropometry is useful for determining various aspects of industrial machineries (10) in order to design the equipment and machines for better efficiency and comfort that is more human. Optimum performance of man–machine system is necessary proper matching of machine requirements with the human capabilities.

Every design should apply the principle of 'user-centered design "(UCD). UCD is the system for an object or an environment to adapt the situation according to humans work task. Therefore, every design should be based on the physical and attitude the users itself (11). The best method to achieve the objectives of a design is to matching between product and user/operator in the context of work (task) as per-shown in Fig.2.

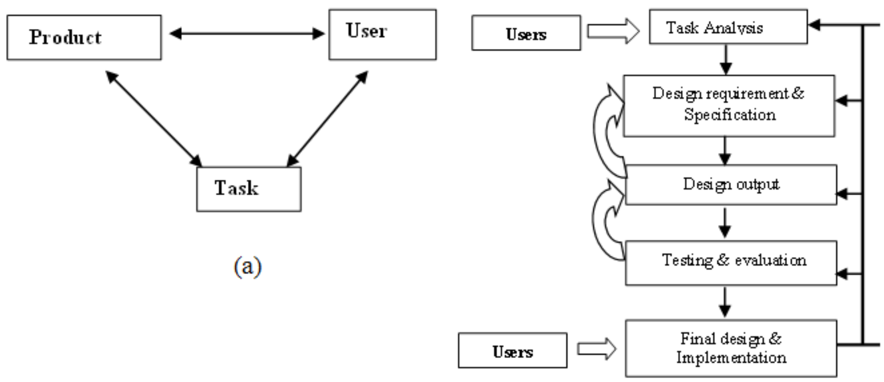

Fig. 2: 'User Centered Design'(a) and User Centered Design Process (b)/ Source : (12)

Therefore, the process of designing a tool for job/work stations, ergonomics factors should be main priority (3, 12-14) as each jobs task performed is different in terms of abilities and limitations on the strength, speed and skill. According (15-16), the design process is dependent on the method and objective of studies while (3) states that a good ergonomics application enhance the safety and health of workers. Failure to apply the principles of ergonomics to work equipment/workstations may cause emotional stress, physical injury and reduce in productivity and quality of work (6).

The objective of this study was to develop a new ergonomics chisel for harvesting based on user centered design approach and evaluate the effectiveness for reducing awkward posture during harvesting.

Materials and Methods

This is a cross-sectional study was conducted in year 2012 at Johor Bahru, Malaysia involving 12 palm oil plantations, which currently harvest young palm trees aged 5 years, and below. Purposive sampling was used to select respondents based on the inclusion criteria; namely, male workers, age ranged between 18 to 49 years old and had experienced using chisel for more than a month. A pretest of the questionnaire was conducted on 10% of the study sample size of different plantation yield $\alpha = 0.823$. Prior to the interviewed questionnaire, respondents were briefed and consent form to participate in the study collected. The questionnaires administered comprise of three sections - social demographic, tool information (a) and selected anthropometric (b) (stature, internal grip diameter) and harvesting tool (length of handle, diameter of handle) measurement as showed in Fig.3.

Fig. 3: Interview session (a), Height and hand grip measurement (b)

The selected anthropometric parameters and current dimension of harvesting tool (chisel) was measured to determine mismatch. Mismatch of body stature and length of handle is defined as any length of handle that is either more than 99% or less than 80% of the body stature. Any value less than 80% was considered as high mismatch, whereas value more than 99% is considered as low mismatch. Thus, any values lies within the range of 80% to 99% were considered as matched (13). Nevertheless, we used 5% percentile and 95% percentile was used as indicator to ensure the proposed new measures meet 95% of the total population.

Video recording is used to determine the body posture of the harvester. Each harvester were recorded for 5 minutes during performing work task. The recording was then used to analyze body posture of harvester working at extreme position through RULA observation (273 harvesters).

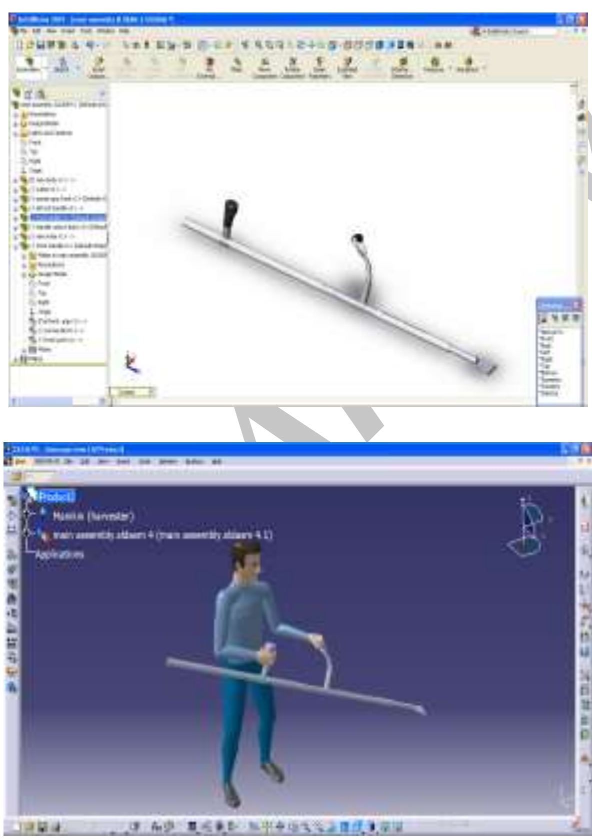

Fig. 4: Solid Work 2007 – technical process (a) and Manikin & simulation process – CATIA (b)

Subsequently, SolidWorks 2007 software was used to build technical drawing in 2D and 3D view for design new harvesting tools (a). All technical aspect builds under this software. The parasolid files in 3D model exported to CATIA software (b). Manikin human body builds according to the sized anthropometric measurement respondents. RULA simulation was perform based on manikin modeling and intergrade with 3D new harvesting tools (Fig. 4). Based on the proposed tool, comparison of body postures were simulated using CATIA based on the real work posture of the harvester.

Results

A total of 273 harvesters were interviewed during the study. The average age was 29.1 ± 6.5 years old. All of the harvesters (100%) were from Indonesia. Overall, 36.3% of the harvesters had never received formal education even at primary schools. The average height and weight with a standard deviation of 162.3 ± 6.4 cm and 54.8 ± 7.0 kg. Majority (82.8%) of the harvesters had normal BMI.

Based on the results in Table 1, most (85.3%) of harvester felt that the chisel they used was heavy. A majority of them (56.8%) had experienced using a chisel within one to two years. Almost all (92.3%) of the respondent used right hand as the dominant hand while half of the (49.5%) harvester had experienced slipping of hand grip while handling chisel more than once in a month. The problem was attributed moisture in addition to the smooth surface of the chisel especially by rain (49.5%) and sweaty palm during normal weather (15.8%).

In terms of effect using chisel during harvesting activities, the result shows that majority (85.3%) of the workers had redness of the hand, numbness (65.9%) as well as blister (83.2%) that occurred on the palm. However, only 39.9% had wounded their hand when handling chisel.

On the other hand, Table 2 shows that the use of current chisel had 94.8% mismatch between length of handle with stature and total (100%)

mismatch between diameter handle with internal grip diameter. Thus, based on the anthropometric size measured, new dimensions (based on the length) at 95th percentile are 173.2cm, matching to 95.2% harvester and (based on the diameter) at 5th percentile are 4.2cm, matching to 95.0% users.

The body posture analysis-using RULA for awkward postures during harvesting activities using existing harvesting tool. A total of 51.6% of the respondents at score 7- where in the action level at number 4 which explains that investigation and changes are required immediately. For score of 5 or 6, a total of 45.1% of the respondents were in the 3 action level, that means investigation and changes are required soon. However, there are only 3.3% of respondents in the total score 3 or 4 and action level at number 2 which describes the action that further investigation is needed and changes may be required as shown by Fig. 5

Table 1: Hand tool information among harvesters

Variables	n	Percentage (%)
Feeling handling chisel		
Light	40	14.7
Heavy	233	85.3
Duration used chisel (year)		
< 1	77	28.2
1 - 2	155	56.8
>2	41	15.0
Dominant hand		
Right	252	92.3
Left	21	7.7
Frequency hand slip during activities		
None	95	34.8
1	44	16.1
>2	134	49.0
Condition hand slip (weather)		
Rainy	135	49.5
Normal (sweat)	43	15.8
Hand effect (Chisel)		
1. Redness		
Yes	233	85.3
No	40	14.7
2. Numbness		
Yes	180	65.9
No	93	34.1
3. Blister		
Yes	227	83.2
No	46	16.8
4. Wound		
Yes	109	39.9
No	164	60.1

N=273

Table 2: Comparing mismatch dimensions with proposed dimensions

Parameter	Percentile		Propose dimensions		Matching (%)	
	Current	Propose	Current	Propose	Current	Propose
Length of handle - chisel	100	95	191.56	173.21	5.2	95.2
Diameter of handle - chisel	100	5	2.80	4.20	0	95.0

* Value in centimeters (cm)

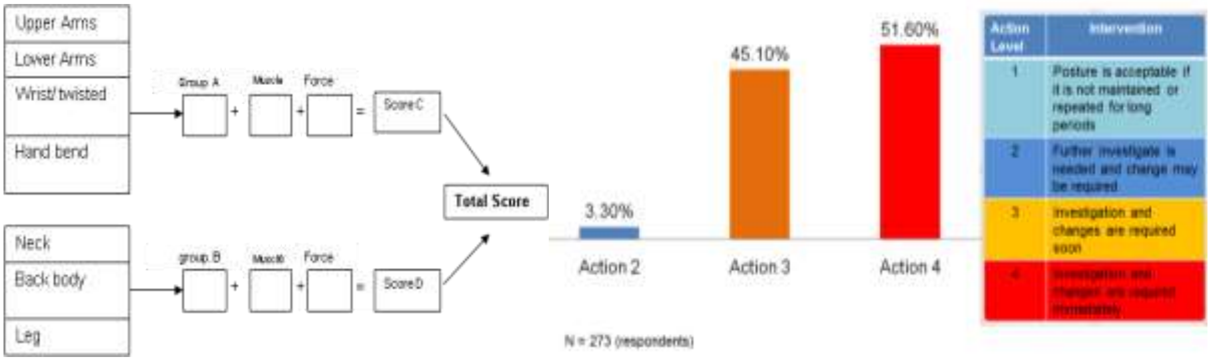

Fig. 5: RULA calculation and RULA result

Figure 6 shows the proposed design for the new harvesting tool which is corresponding to the proposed anthropometric data. The proposed design were in consideration of existing problems identified by the initial study such as awkward posture such as stooping and hand positions as well as mismatch of dimension between user and tool. Adapting from existing chisel, the special features of the new design is the adjustability and flexibility of handle and heights accordingly to user. It was also designed such that the chisel will be easy to handle, without any complex mechanical operation required and no special training required.

RULA analysis was done through simulation 3D modeling by performed harvesting activity between new design and conventional tools.

The results of comparison the RULA analysis through simulation between new designs and current tools showed at Fig. 7 and Fig. 8.

Fig. 6: New design harvesting tool.

The comparison shows the new design has significantly reduce ergonomic risk, especially in awkward or bending posture. The simulation shows that the new design were able to reduce awkward body posture to score of 3 (low risk) compared to the body posture using current chisel – score of 7 (high risk).

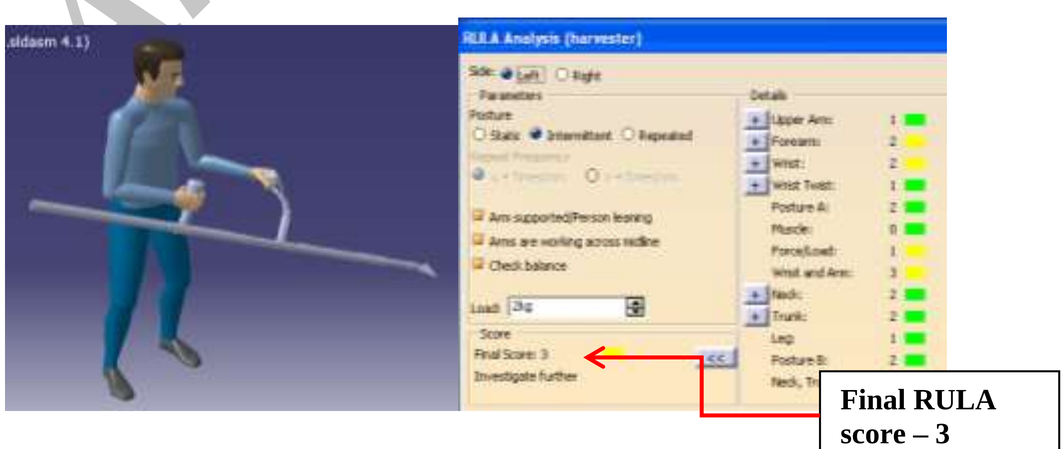

Fig. 7: Simulation new design harvesting tools

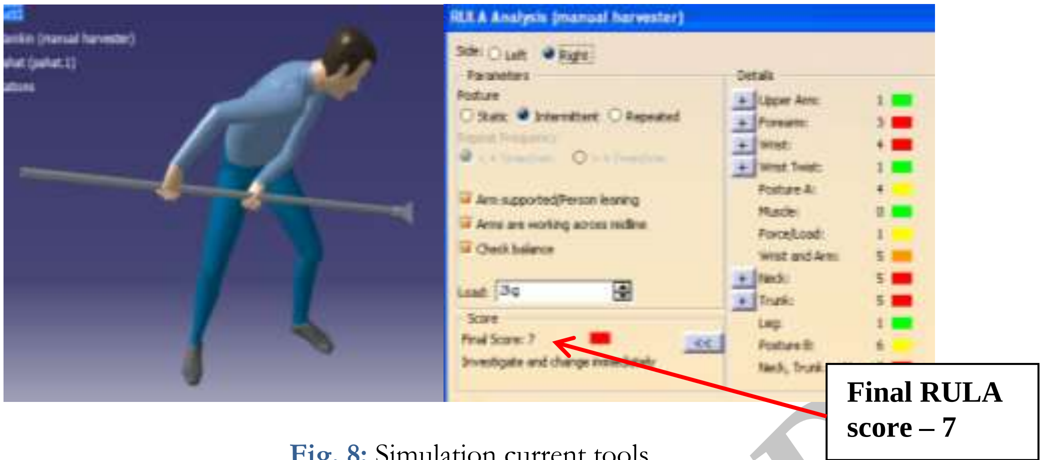

Fig. 8: Simulation current tools

Discussion

Manual handling and awkward posture were common in farms and has been associated with potential of injuring the lower back (17-18). Harvesting activities usually require harvester to bend excessively and perform repetitive actions (19). Harvesting activities put a high stress on the lower back during awkward postures particularly for tree height below 3.4m (20). Risk factors have a significant relationship with back pain when the body frequently bend forward while harvesting (odd ratio = 5:09; 95% CI = 1:42 to 18:27) (2).
The height of oil palm tree below 5.5 m require bending posture over working conditions which can cause serious injury to the harvester (4), as confirmed by another study (21). The injury is caused by three main factors: 1) height of tree when cutting the fruits, 2) size of bunch and weight during lifting and 3) using excessive force when cutting fruits as conventional tool was used as harvesting tools (22).
The effectiveness of the new designs was determined by comparing current harvesting tool through RULA simulation analysis where the score was potentially decreased from 7 to 3. The change was corresponding to the design of handle that minimizes bending posture. Customize of handle for specific work task according to users and situation can improve the health of workers (23). When optimum diameter for a tool handle was used, the muscle exert the minimum force required to hold the tool and perform gripping activities hence reducing the force needed for gripping a tool, protects the underlying joint structures and reduces the risk of developing cumulative trauma associated with repetitive task which normally require high grip forces and in awkward postures (24).
The result shows that there is possibility of improving the body posture hence decreasing the MSD symptom to a minimal simultaneously improving health level and generally increasing productivity of harvester using the proposed tool. However further study is anticipated in order to build the prototype and testing the utility in the field.

Conclusions

The current harvesting tool used by the oil palm workers in Johor, Malaysia was not matched to the anthropometry of oil palm harvesters in Johor besides the design, which require workers to work at awkward postures. Due to the mismatch, various health effects were reported by the workers especially of the hand such as redness, numbness and blister of the palm. The proposed dimensions of new tool show that the new design fit more than 90% of the harvesters' anthropometrically. In addition, the RULA simulations showed that the new designs potentially reduced awkward body posture compared to the current harvesting tool (chisel). The proposed new design was developed based on problem gather from users such as awkward body posture – bending, mismatch of design

– dimension with anthropometric and problem of harvesting tools.

Ethical considerations

The study was approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, University Putra Malaysia, Selangor, Malaysia. The reference number of ethic letter: UPM/FPSK/P-ADS/T7-MJKEEtikaPer/F01 (JKK (U) _Dis (11)14).
Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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