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Motion Study to Increase The Effectiveness and Safety of Oil Palm (*Elaeis guineensis* Jacq) Manual Harvesting

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. Introduction

Oil Palm (*Elaeis guineensis* Jacq.) is the most potential il producer plant in tropical area. Indonesia is the biggest alm oil producer in the world, which is cover 7.824.623 a and produce 19.844.901 tonnes [1] which is more than 5 % of the world total oil palm production [2].

The oil can be extracted from the fruits and kernel as ell. Palm oil industries continue to grow due to the rowing demand of the oil for food and non edible products ıcluding bio-fuel, soaps, detergent and surfactants, osmetic, pharmaceuticals and a wide variety of other ousehold and industrial product [3].

Harvesting is the most important and burdensome ork in the oil-palm industries. The success of harvesting ill support the achievement of the productivity of the lant [4]. Most of oil palm harvesting activity is done by ıuman power' manual handling, therefore the activity ıay cause musculoskeletal disorders (MSD), work safety nd health problem.

This research is deal with ergonomic's motion study to ind out the risk of the manual handling and to develope etter work motion and so the manual harvesting can be one in more safety, efficient and productive.

The aims of this research is to reveal the movement attern of the work motions and distribution on the orresponding body parts and then to develope a good ractice model for the manual harvesting procedure.

:. Material and Method

The data were collected in June until August 2012 from ıree plantation which is located in Sumatra, Kalimantan nd Sulawesi [5]. The data consist of harvesting video ecord (25 male harvester), antrophometry (141 male arvester) and tool's dimention. There are two type of tools, dodos' and 'egrek '. 'Dodos' is a traditional hand tool used or push harvesting method which is apply for less than 3 m eight of targeted bunches and 'egrek' is traditional hand ool used for pull harvesting method which is apply for ıore than 3 m height of targeted bunches.

The work motion were analyze based on capture picture f harvesting video record (3 work sequence and 8 ıotion repetition for each subject). Then, motion risk nalysis were conducted basen on natural Range of Motion nROM).

;. Result and Discussion

Figure 1 and 2 show the sample of movement pattern of dodos' and 'egrek' harvesting activity which is discribed ith three work sequence.

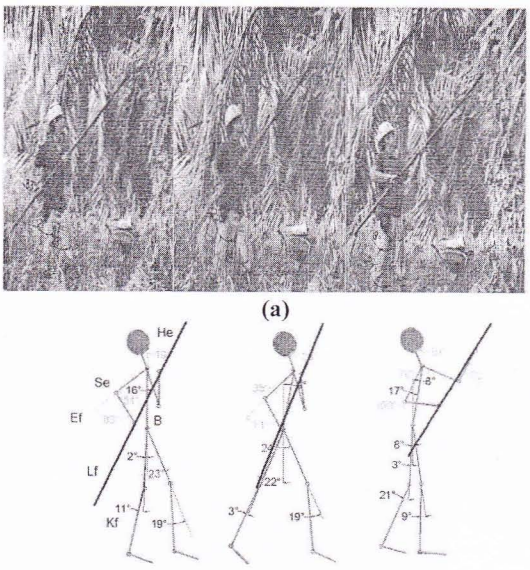

Fig 1. 'Dodos' harvesting activity (a) video capture, (b) mannequin model analysis

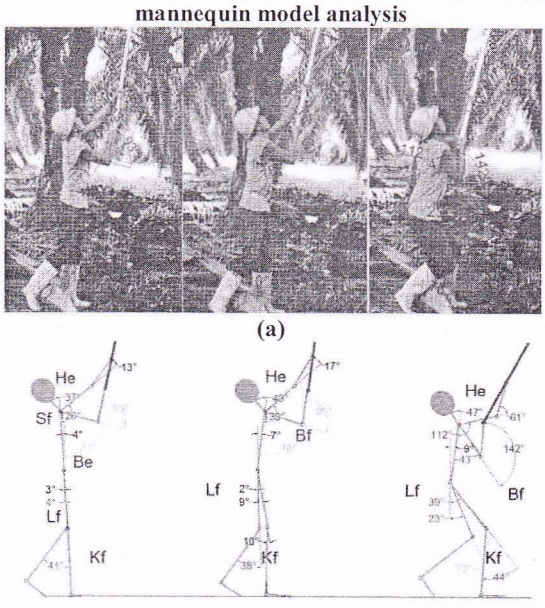

Fig 2. 'Egrek' harvesting activity (a) video capture, (b) mannequin model analysis

As it's shown in Table 1, the result of ROM analysis reveal that the ergonomic risk occur mostly in the upper body, such as the neck (H), shoulder (S) and forearm (E), generally both in 'dodos' and 'egrek'. Meanwhile, the lower body such as upper leg (L) and lower leg (K) are in safe zone. From the data we know that both of 'dodos' and 'egrek' method almost only have neck extension (He) which is have higher ergonomic risk at 'egrek' than 'dodos' method. Also at the shoulder, 'egrek' method almost only have shoulder flexion (Sf) which is have higher ergonomic

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risk than 'dodos' method which is have both shoulder extention and flexion. It's reveal that 'egrek' method which is pulling activity has the risk from flexion movement and 'dodos' method which is pushing activity has both flexion and extention movement.

Table 1. Distribution of ergonomic risk in the manual harvesting activity

a) 'Dodos' harvesting activity for less than 3m height targeted bunches (push harvesting method)

	S	Ef		Sf		Se		Bf	Be	Hf	He	Lf		Kf	
		R	L	R	L	R	L					R	L	R	L
	C1			68				23				44	31	68	58
	A1	78	96	51	56			41		32	28	34	33	71	46
	A2			53				22	12			25	26		
	A3			7	81		30	21	4		29	28	36	30	33
Average	A4					25	6	10	18			48	44	53	71
	A5			54				24	15			46	13	47	38
	B1			90	55		26	41	13			39	29	61	89
	B2				50			25	9			48	25	64	58
	B5	88		85				33	4			17	52	59	72

b) 'Egrek' harvesting activity for more than 3m height targeted bunches (push harvesting method)

	S	Ef		Sf		Se		Bf	Be	Hf	He	Lf		Kf	
		R	L	R	L	R	L					R	L	R	L
	C2		119			8		33				29	39	34	73
	A1							12				9	37	29	43
	A2				84			18				28	20	45	37
	A3	112						17				44	20	41	35
	A4			51	90	25		17	2			14	18	52	38
Average	A5			90				24				16	26	41	38
	A6							20				30	33	77	64
	A7			44				24	12						
	A8			64		7		16				11	8		
	A9							24	12			29	55	56	57

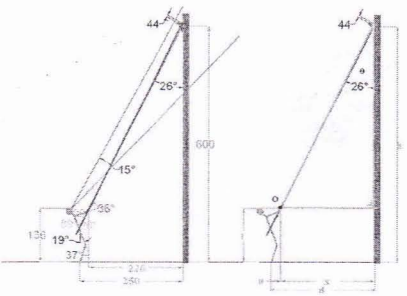
The ergonomic risk at the elbow for two kind of harvesting method is the same, they belong to dangerous zone (red zone). Meanwhile, 'egrek' method almost only have back flexion (Bf) which is more safe than 'dodos' method. It's have both back flexion and extention which is have higher ergonomic risk at the extension movement. Generally for lower body, 'dodos' method has higher ergonomic risk than 'egrek' method. Especially for lower leg, it's has higher ergonomic risk than upper leg because of flexion movement.

According to ROM result, we know that we must minimize ergonomic risk at the upper body movement. To develope better work motion and so the manual harvesting can be done in more safety, efficient and productive, we develope a simulation which is created from the information regarding the level of risk distribution and movement of each body part harvesting, harvesters mannequin model and dimensions tool data. For the simulation, we use percentil 5 of harvester because the sorter harvesters, they will have the higher ergonomic risk. From the simulation, we know that to create the safe and better movement, the angle between the tree and 'egrek' must be 26°. The results of the simulation show that the working radius for cutting is 1.5 m, 2.5 m, 5.5 m and 8.5 m for the maximum height of the tree 3, 6, 12 and 18 m.

From the illustration (Fig 3) we can make the equation of the formula.

$$d = 0.5(h - t) + 0.3 \qquad (1)$$

From the formula above, d is the distance between harvester's position and the tree, h is bunches's height and t is the harvester's height while he doing pulling activity. The good practice models for 'egrek' revealed that the ideal position of harvester is 30-45° relative from the position of the bunch.



Notes
h : The bunches's height (m)
t : The harvester's height (m)
O : the intersection between hand grip of 'egrek'and the pararel line of harvester's head
x : the distance between point O and the tree (m)
a : The distance between point O and the harvester (m) its length is approximately equal to the length of the forearm that is 0.3 m
d : the distance between harvester's position and the tree (m)
θ : The angle between the trees and 'egrek' (°)

Fig 3. The ilustration of the safe distance formula

If the average radius of the palm oil's stem is 20 cm [6], so the safe distance for harvest the bunches are 1.7 m, 2.7 m, 5.7 m and 8.7 m from the center of the rod for maximum height of the tree 3, 6, 12 and 18 m. Figure 4 show the working radius for cutting in every bunches's height.

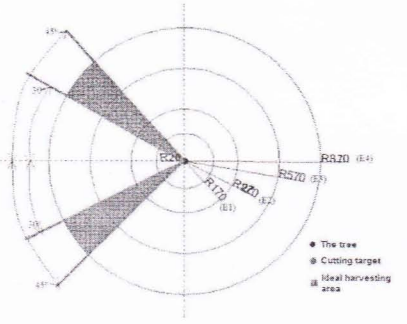


Fig 4. Simulation of good practice model for optimum work of harvesting area

4. Conclusion

The result of ROM analysis show that the ergonomic risk occur mostly in the upper body, such as the neck, shoulder and forearm. The good practice models for 'egrek' revealed that the ideal position of harvester is 30-45° relative from the position of the bunch and the formula for the distance is $d = 0.5 (h-t) + 0.3$, where d is the distance between harvester's position and the tree, h is bunches's height and t is the harvester's height.

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