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ASSESSMENT OF WORK POSTURES ON NON-MECHANICAL RICE HARVESTING (CASE STUDIES IN BANTUL AND SLEMAN DISTRICTS, DIY PROVINCE)

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ABSTRACT

Rice harvesting is a high ergonomic risk due to the working position, an awkward posture, and the repetition activity. Rice harvesting causes body pain in the part of low back, hand, and wrist. This study aims to (1) identify the characteristics of non-mechanical rice harvesting; (2) determine the working posture of rice harvesters using the Ovako Working Assessment System (OWAS) method, Quick Exposure Checklist (QEC), Rapid Entire Body Assessment (REBA), Postural Ergonomics Risk Assessment (PERA); and (3) determine the best method to assess harvesters work posture. An observation was conducted to nine of healthy workers in Bantul and Sleman districts, Daerah Istimewa Yogyakarta (DIY) province. The questionnaire was set to collect respondent demographics data. Data for harvester body posture (neck, trunk, leg, wrist, lifting load, shoulder) repetition, duration and force were collected by observation in the field. A sickle was used to cut rice straw, while a manual *gepyok* and mobile hand thresher was used to threshing rice panicles. Four methods were applied to assess the work posture, *i.e.*, OWAS, QEC, REBA, PERA methods. Based on observation, five workstations were identified: (1) cutting rice straw, (2) transporting rice straw, (3) threshing of panicles, (4) sorting, and (5) packaging and transporting. REBA and PERA showed a similar trend of the ergonomic risk, high to low risk took place in workstation transporting rice straw, packaging and transporting, cutting, and threshing. The assessment of work posture that is most suitable for non-mechanical harvesting methods was the REBA method with an accuracy of 92.9%.

Keywords: ergonomic, non-mechanical, posture, rice-harvesting

INTRODUCTION

Background

Rice harvesting activities sometimes use heavy equipment, awkward postures, and lots of repetitive movements. These factors were related to Work-Related Musculoskeletal Disorders (WMSDs) or MSDs. The best way to reduce WMSDs is to redesign equipment and process improvements using the principle of ergonomics. Relatively small changes in equipment design can make a big difference in performance (Baron *et al.*, 2001). The use

of new *gepyok* design in conventional rice harvesting can improve the harvester's working posture, reducing work-related pain, and harvesting workload (Sa'diyah *et al.*, 2019). New *gepyok* design is a triangular prism-shaped object, with one side made of rows of small metal which is used as a foundation for slamming rice stalks so that the grain falls.

To secure worker safety from ergonomic risk, specifically on posture, there are some methods that could be employed to evaluate and assess it. There are some methods of worker posture assessment to determine the risk level of workers MSDs, *e.g.* Quick Exposure Checklist (QEC), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), the Occupational Repetitive Action (OCRA) and others (Stanton *et al.*, 2005). These methods identify the risk of worker posture by evaluating and assessing the body part movement trunk, hand, leg, and other factors. Every method has merits and demerits.

Many workers stand for long periods of time without the opportunity to walk or sit down. Working in a standing posture on a daily basis can cause pain in the soles of the feet, swelling in the legs, enlarged blood vessels, muscle fatigue, low back pain, stiffness in the neck and shoulders, and other health problems (Waters & Dick, 2015). In the case of a pregnant worker, these effects can cause preterm birth and spontaneous abortion (Vaidya *et al.*, 2014).

An activity such as repetitive work and awkward posture are the main factors of ergonomic risk (Chander & Cavatorta, 2017). Correlation of a worker ergonomic risk and MSDs has not known certainly, because 83% of worker does not realize ergonomic action (Boschman *et al.*, 2015).

Karhu *et al.* (1977) published the first method of harvester posture assessment, Ovako Working Assessment System (OWAS). It was a simple method but does not consider the interaction of worker's body part; such that the accuracy is less (Hellig *et al.*, 2018). The advantages of this method are evaluating leg posture when sitting and walking. QEC was designed to evaluate the work experience of the observer, practitioner, and workers (Li & Buckle, 1998). RULA and REBA evaluate worker posture more detail by including movement of the neck, shoulder, arm, and hand, clutch as well as load lifting frequency. REBA developed by Hignett & McAtamney (2000) for industry application. It provides rapid and simple methods to measure several worker postures which risky to WMSDs.

REBA defines a neutral posture by evaluating the angle of body joints, and this method classifies the worker's leg position. These points do not include in the RULA method (McAtamney & Corlett, 1993). RULA has excellent performance to evaluate the ergonomic risk in case of working while sitting (Al Madani & Dababneh, 2016). Chander & Cavatorta (2017) introduces the PERA method that can be used to evaluate the ergonomic risk of short cyclic work. It enables us to determine the main factor of cyclic work by focusing on the analysis of worker posture when working (Ahmadi & Salmanzadeh, 2018). PERA overcomes obstacle the assessment method of ergonomic risk for cyclic work.

Rice harvesting causes body pain in the part of the low back, hand, and wrist (Swangnetr *et al.*, 2014). Physiological fatigue due to working while standing for long periods can be assessed subjectively with a survey questionnaire using the Borg scale or the Body Part Symptom Survey (van Dieën, 2010).

Period of work time has not considered in OWAS and REBA. It makes them cannot be applied to evaluate a cyclic work (Chander & Cavatorta, 2017). Rice harvesting covers all activity in the field, starting from cutting rice straw to releasing the grains from panicles (Sulistiaji, 2007). It includes manual working such as cutting rice straw by using a sickle, transporting rice straw to thresher machine, threshing the grains, sorting the grains, weighing, packaging, and transporting sacked rice. These activities can be done by standing,

bending, walking while bringing a mass, standing for the operating machine, and squatting down. It means that rice harvesting activities are an awkward work posture, *e.g.* squatting down > 60°, walking while bringing a huge mass. This study was focused on evaluating using OWAS, QEC, REBA, and PERA methods for work posture assessment of rice harvesting by using the non-mechanical method. Work posture is a significant cause of muscle problems MSDs (Iridiastadi & Yasierli, 2014).

Objective

The study aimed to learn OWAS, QEC, REBA, and PERA methods for work posture assessment of rice harvesting and determine the best method for assessing the harvester's work posture. The results of the assessment of work posture and assessment of the suitability of the physical size of the tool with anthropometry of workers will be used to redesign work equipment to reduce MSDs risk.

METHODOLOGY

The characteristics of respondents

Respondents were nine healthy harvesters in Bantul and Sleman districts, Daerah Istimewa Yogyakarta province. The questionnaires were used to collect respondent demographic data. Work posture data in the form of video recordings and photographs were collected by observing harvesting in the field. Data were collected on 14-16th November 2019. The respondents consisted of 44% female harvesters and 56% male harvesters. The average age of respondents was 53 years, with 21 years of experience as harvesters. Sixty percent of respondents were of interest in elementary school.

Non-mechanical method of rice harvesting was defined as (1) manual cutting and threshing, (2) manual cutting and semi-mechanical threshing. The harvester worked full a week during harvesting season. Rice harvesting starts at 05.30 AM by cutting rice straw. This activity is fast and continual to collect as much as possible the materials before the sun is getting hotter. All member of the group takes a break at 08.00 AM for breakfast. Some harvester groups set up tents to reduce the impact of the sun's heat.

The design and setting of the study

Four methods, e.g. OWAS (Karhu *et al.*, 1977), QEC (Li & Buckle, 1998; (Godsiff *et al.*, 2008)), REBA and PERA (Chander & Cavatorta, 2017) were applied to evaluate work posture.

OWAS method does not evaluate posture of neck, trunk, and hand in detail but it considers posture of leg and position of working (sitting on the chair, moderate squatting down, and walking). The evaluation of work posture in QEC method is conducting by observer and worker. It is similar with OWAS, in which the evaluation on body parts have less attention but the repetitive work has been more explored. REBA method is intent in evaluating upper part of body. Furthermore, it includes evaluation on the stand up straightness of leg position, coupling, static muscle work (holding something more than 1 minute), and repetitive working while unstable standing. PERA method more concerns in evaluating work posture when repetitive working in a short cycle.

The study started by documenting the rice harvesting activity. Data was input to OWAS, QEC, REBA, and PERA, and classified into Method Score. Each method has a different final score that listed in the S column of each method. OWAS score: 1-4, QEC score: 40-70%, REBA final score: 1-12 and PERA score 1-7. The score of each method is classified into the Action Level in the AL column of each method. OWAS action level: 1-4, QEC action level: 1-4, REBA action level: 0-4, and PERA action level: 1-3. This action level illustrates the level of risk faced by the activity assessed by its work posture (level of risk column). It can be used to assign the recommendation to minimize MSDs of the worker. The method score, action level, risk and recommendation of each method was classified in Table 1.

Table 1. The Method Score, Action Level Score, Level of Risk and Recommendation of OWAS, QEC, REBA and PERA Methods

Methods								Level of risk	Recommendation
OWAS*		QEC**		REBA**		PERA***			
S	AL	S	AL	S	AL	S	AL		
1	1	≤ 40	1	1	0	A < 4	1	Negligible risk	Acceptable
2	2	41-50	2	2-3	1			Low risk	Further investigation, manipulations are required
3	3	51-70	3	4-7	2	4 ≤ A< 7	2	Medium/ possible risk	Further investigation and manipulations are urgent
4	4	>70	4	8-10	3	A ≥ 7	3	High risk	Investigation and straightway manipulation
				11+	4			Very High risk	Investigation and straightway manipulation

Note: S = method score; AL = method action level; * = Hellig *et al.*, (2018); ** = Stanton *et al.*, (2005); *** = Chander & Cavatorta, 2017

RESULTS AND DISCUSSION

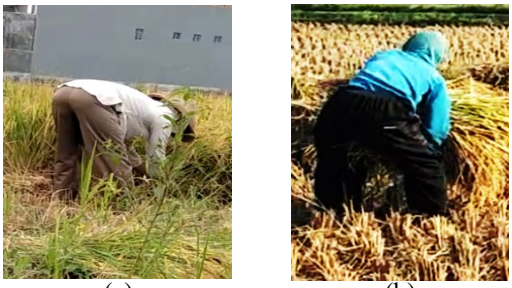
Manual and Semi-Mechanical Rice Harvesting Method

Non-mechanical harvesting activities start from cutting rice straw manually using sickle, followed by threshing activities using *gepyok* or hand thresher. *Gepyok* and hand thresher was put in the middle part of the land. Rice straws collected around the thresher. Simultaneously, the harvester did threshing the grain from panicles. The threshing activity was followed by the sorting activity. After these two activities completed, the grain was packed and transporting. Based on these steps, this study identified 5 work-stations in manual and semi-mechanical rice harvesting and 19 work elements (Table 2).

Table 2. Work-stations and Work-elements of Non-Mechanical Rice Harvesting Method

No	Work-stations	Work- elements
1	Cutting	(a) cutting, (b) placing, (c) moving & relaxing
2	Transporting	(a) taking the collected rice straw, (b) amassing &lifting, (c) transporting the amassed rice straw to the thresher
3	Threshing	(a) placing thresher, (b) taking rice straw, (c) carrying, (d) threshing the grain, (e) disposing the straw
4	Sorting	(a) sorting the straw, (b) sorting the rice, (c) winnowing, (d) collecting the selected rice
5	Packaging and tranporting	(a) preparing the sacks, (b) measuring & packaging, (c) lifting the sacked rice, (d) transporting the sacked rice

Activities at each workstation were recorded in Figure 1-3.



(a) (b)

Figure 1. (a) Cutting, (b) Transporting

Figure 1 shows cutting activity and transporting rice straw to threshing workstation. Activities in cutting and transportation are mostly done by bending. Figure 2 was a threshing activity, (a) manual *gepyok*, (b) hand threshing.

(a) (b)

Figure 2. Threshing Activity: (a) Manual *Gepyok*, (b) Hand Thresher

Sorting activity is the activity of separating unhulled rice from the following pieces of rice stalks, is done by taking the material at the bottom of the thresher by squatting. Grain is packed in 50 kg sacks.

Sacks were delivered to the owner's house (Figure 3).

(a) (b)

Figure 3. (a) Sorting, (b) Packaging and transporting

Work posture assessment

The score of work posture assessment were done using 4 methods presented in Table 3. The workstation 3 describes manual *gepyok* (3a) and semi-mechanical Hand Thresher (3b) activities. Score was derived from a posture assessment using the appropriate method, respectively. From table 3 PERA method, some activities have an extreme high score (score 27) such as in the rice straw cutting and in the manual threshing way of *gepyok*. At work-station 1, 70% of the time was spent cutting rice stalks with a bow, resulting in a very high risk assessment.

In manually, worker must exert a very large force that is not assessed in other methods. Cutting rice activity, while bending almost 90^{o}, leads to the judgment of the neck and the trunk in the REBA method was highly rated (11). The REBA assessment was very high in the amassing & lifting (2b) because the activity by bending and carrying the load. Similarly, this phenomenon also occurs in packaging and transportation activities. The OWAS and QEC assessments did not give the same results because the important considerations in these methods differed from the REBA and PERA. Table 3 shows the action level for each method and each work element.

Table 3. Score Posture and Action Level of Each Work Element

No.	Work element	Methods							
		OWAS		QEC		REBA		PERA	
		S	AL	S	AL	S	AL	S	AL
1	(a) cutting rice	2	2	2	2	11	4	**27**	3
	(b) placing	2	2	1	1	7	2	4	2
	(c) transporting	1	1	1	1	1	0	2	1
2	(a) taking the collected rice	2	2	1	1	7	2	18	3
	(b) amassing &lifting	1	1	2	2	11	4	12	3
	(c) transporting the amassed rice	1	1	1	1	4	2	6	2
3a	(a) placing thresher	3	3	2	2	7	2	*	*
	(b) taking rice straw	1	1	1	1	6	2	4	2
	(c) carrying	1	1	1	1	4	2	4	2
	(d) threshing	1	1	1	1	5	2	**27**	3
	(e) disposing the straw	1	1	1	1	2	1	1	1
3b	(a) placing thresher	3	3	2	2	7	2	*	*
	(b) taking rice straw	1	1	1	1	6	2	4	2
	(c) carrying	1	1	1	1	4	2	4	2
	(d) threshing the grain	1	1	1	1	5	2	18	3
	(e) disposing the straw	1	1	1	1	2	1	1	1
4	(a) sorting the straw	4	4	2	2	10	3	**	**
	(b) sorting the rice	4	4	2	2	10	3		
	(c) winnowing	2	2	1	1	7	2		
	(d) collecting the selected rice	2	2	1	1	8	3		
5	(a) preparing	1	1	1	1	1	0	1	1
	(b) measuring & packaging	4	4	1	1	7	2	18	3
	(c) lifting	3	3	3	3	11	4	6	2
	(d) transporting	3	3	2	2	11	4	18	3

Note: S = method score, AL = method action kevel, * = non cyclic work because only once in a day, ** = duration is long time

Table 4. Classification of Risk Score Into 3 Classes

	Work element	Score							
		OWAS		QEC		REBA		PERA	
		RS	avg	RS	avg	RS	avg	RS	avg
1	(a)cutting	2		2		3		3	
	(b)placing	2	1,7	1	1,3	2	2,0	2	2,0
	(c)transporting	1		1		1		1	
2	(a)taking	2		1		2		3	
	(b)amassing	1	1,3	2	1,3	3	2,3	3	2,7
	(c)transporting	1		1		2		2	
3a	(a)placing	3		2		2		*	
	(b)taking	1		1		2		2	
	(c)carrying	1	1,4	1	1,2	2	1,8	2	2,0
	(d)releasing	1		1		2		3	
	(e)disposing	1		1		1		1	
3b	(a)placing	3		2		2		*	
	(b)taking rice	1		1		2		2	
	(c)carrying	1	1,4	1	1,2	2	1,8	2	2,0
	(d)releasing	1		1		2		3	
	(e)disposing	1		1		1		1	
4	(a)sorting	3		1		3		2	*
	(b)sorting rice	3	2,5	1	1,5	3	3,0	2	
	(c)winnowing	2		1		3		3	
	(d)collecting	2		1		3		1	
5	(a)preparing	1		1		1		1	
	(b)measuring	3	2,5	1	1,75	2	2,3	3	2,25
	(c)lifting	3		3		3		2	
	(d)transporting	3		2		3		3	

Note: The Green indicates low risk, yellow is moderate, and red is high risk

From Table 3, this action level is obtained by following the work posture assessment stages in each method as shown in Table 1. The 1st work element was the cutting rice straw with OWAS score 2 action level 2, QEC score 2 action level 2, REBA score 11 action level 4, PERA score 27 action level 3. The score of the work elements in one workstation was averaged. Action level values for OWAS method are 4, QEC 3, REBA 5 and PERA 3. To compare four methods, a new classification for action level was made. For comparing the method, the average score (x) was classified into 3 classes. Low risk (score: 1) if $x < 2$, the color is green, medium risk (score: 2) if $2 \leq x < 3$, the color is yellow, and high risk (score: 3) if $x \geq 3$, the color is red. The result can be seen in Table 4. Referring to Table 1, recommendations for the green ones are good work postures and risks are acceptable. The yellow ones means that need further investigation and may need some improvements in the future. The red ones mean need investigation immediately and straightway improvement.

Based on Table 4, the OWAS method gives a low rate at workstations 1, 2, and 3, medium at workstation 4 and 5. The QEC method evaluates all workstation in low risk. The REBA and PERA methods provide the same risk assessment results in terms of the medium risk workstation sequences in terms of MSDs. If sorted from those most at risk to those not at risk, the sequence of workstations was 4, 2, 5, 1, and 3.

The assessment was carried out by identifying the percentage of body parts and activities of rice harvesting that have been assessed by the REBA and PERA methods (Table 5). From Table 5, it can be seen that the activity of harvesting rice in paddy fields involves the neck and trunk posture, which is closely related to the angle of movement, where the neck posture is assessed in the QEC, REBA and PERA methods, while the trunk is assessed by all methods.

Table 5. Body Part and Activity that Assess by OWAS, QEC, REBA and PERA

	Part of the body / activity	OWAS	QEC	REBA	PERA
1	Neck	-	*	*	*
2	Trunk	*	*	*	*
3	Angle of movement	-	-	*	*
4	Leg (standing/ kneeling/walking)	*	*	*	*
5	Load	*	*	*	-
6	Upper arm/shoulder	*	*	*	*
7	Static muscle/monotonous movement	-	*	*	-
8	Dynamic movement	*	*	*	*
9	Repetitive task	-	*	*	*
10	Coupling	-	-	*	-
11	Force	-	-	-	*
12	Duration of task	-	*	*	*
13	twisted	*	-	*	-
14	bending	*	-	*	-
	Quantity	7	9	13	9
	Percent accuracy (%)	50	64.3	92.9	64.3

The angle of movement of the neck and trunk is only assessed in the REBA and PERA methods, not in the OWAS and QEC methods, etc. In total, there are 12 characteristics of rice harvesting activities that are closely related to work posture assessment. Based on Table 5, posture assessment using the REBA method is an appropriate method for rice harvesting activities, considering that 92.9% of posture characteristics can be assessed by REBA. The REBA method can be used to assess the posture of all parts of the body and is very good for assessing work that is static and dynamic (Hashim et al., 2012). The OWAS method assesses 7 harvest characteristics out of 14 valued or 50.0%, QEC 64.3%, REBA 92.9% and PERA 64.3%.

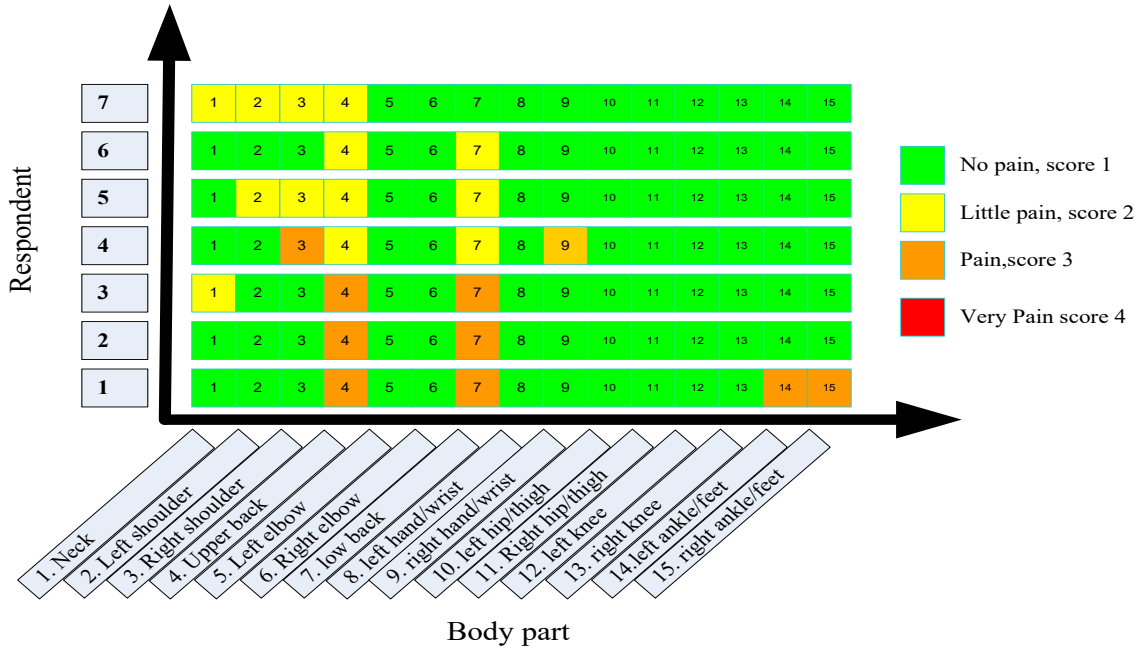


Figure 4. Pain Mapping due to Work in Rice Harvesting by using Manual *Gepyok* Method (Mulyati *et al.*, 2019)

To develop corrective measures such as in the case of work posture assessment, it is necessary to assess workload by analyzing the risk of MSDs (Hellig *et al.*, 2018).

Supporting data are required like Standard Nordic Questionnaire that could describe an injury or pain when rice harvesting was finished. Mulyati *et al.*, (2019) realized that manual *gepyok* and semi mechanical rice harvesting by using hand thresher issued score of pain assessment as seen in Figure 4 and 5. The Figure illustrates pain assessment when working that evaluated objectively by worker using Standard Nordic Questionnaire. The color of green means there is no pain in the body. Yellow, orange, and red colors indicate the level of pain when working is finished. Yellow means little pain, orange pain, and red very pain.Y axis should be Respondent and X axis should be "body part". The colored boxes inform pain level of workers after full day activity.

On Figure 4, respondent number 1 have 2 colored boxes, green, and orange. The orange box with written number 4 and 7 means the pains were in upper and lower back, while number 14 and 15 means the pain were at the left and right ankle/feet. The green boxes state no pain.

Manual workers using *gepyok* had feel pain in the upper and lower back because they must exert energy during threshing the rice. As a result of the use of considerable energy, the workload represented by the heart rate of the worker (± 115 beats/minute) is at moderate levels (Mulyati *et al.*, 2020). This workload is at the same level of a hand tractor operator who has a heart rate of 100-125 beats/minute (Sulnawati *et al.*, 2016). If the rice harvester feels pain due to the use of excess muscle, the hand tractor machine operator's pain is caused by the vibration and noise of the engine.

Figure 5 shows the results of work-related pain mapping for threshing using a hand thresher. On the Figure 5, respondent number 2 feel pain in lower back. The left hand less pain than right hand. Since the harvesting workers must hold the rice straw tightly from work element number 2 to 5. This work posture is a static muscle. Charles *et al.*, (2017) underlined that static muscle in long leads the blood does not flow smoothly, the energy decrease, lactic acid in the muscle is accumulated then raise fatigue, pain increases while hand power declines.

Working while standing in a long time induces fatigue that happen after 2 hours standing all the time, where it raises a static contraction in and back too.

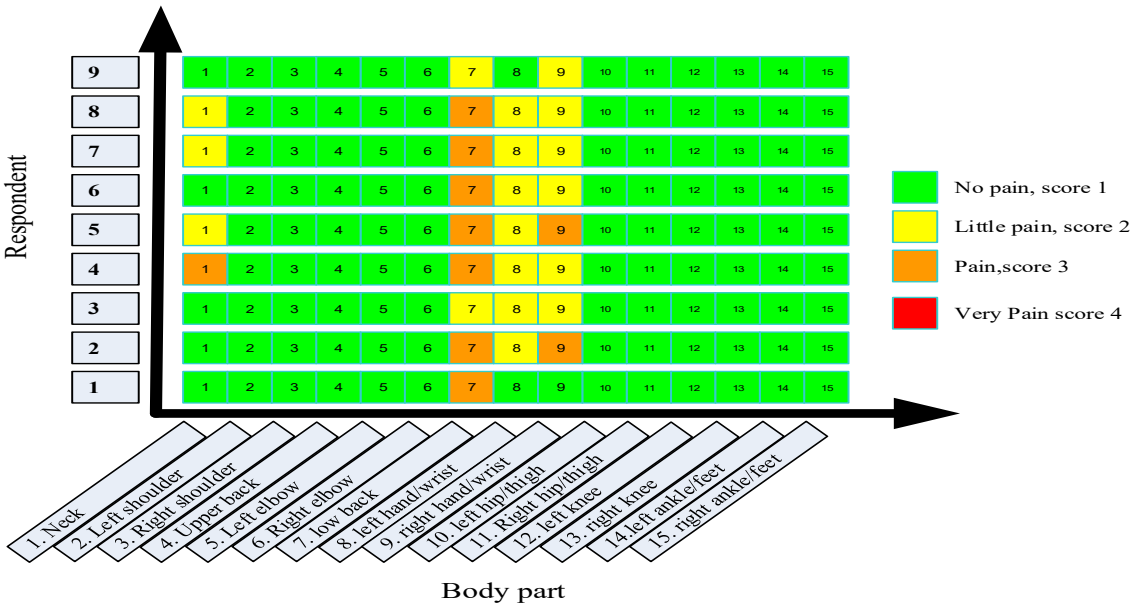


Figure 5. Pain Mapping due to Work in Rice Harvesting by using Semi-Mechanical Method (Mulyati *et al.*, 2019)

When experiencing static contraction, the calf muscle malfunctioning then uncomfortable and tired (Halim *et al.*, 2012). High scored activity by REBA were stoop> 60° in workstation 1,2,4,5, lifting a mass in workstation 2 and 5 which caused bad impact in lower back and hands. The manual harvest method *gepyok* and semi-mechanical hand thresher has the same REBA posture score but has a different score of pain due to Standard Nordic Questionnaire.

Harvesting rice by *gepyok* resulted pain in the upper and lower back. In the threshing process harvester should raise the hand holding the rice straw followed by bending the tip of the rice straw into the *gepyok* tool. The pain in the upper and lower back is caused by the activity position of higher than the shoulder and quickly bending over 60° while swinging hands firmly.

In semi mechanical threshing by hand thresher, the harvester holds the rice straw and directs the tip to the thresher cylinder until the grain is released. Painful limbs are reported at the lower back and hand. Harvester must hold rice straw continuously. Hold rice straw in a static muscle cause a fatigue.

CONCLUSION

Activities of non-mechanical rice harvesting were involving static and dynamic muscles, repetitive, most were cyclic with short cycle time, and using a tremendous force when threshing manually. Harvesters work on standing posture for more than 50% of working time, stoop more than 60%, squatting or kneeling, and carrying heavy loads. Posture assessments using OWAS and QEC methods showed that the activity could be classified as a low-moderate risk level. While assessment using REBA and PERA methods results a moderate-high risk of harvesting and showed a similar trend of the ergonomic risk. Work posture assessment method that had most suitable for non-mechanical rice harvesting was the REBA method have accuracy of 92.9%.

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