Chapter 19
Ergonomic Evaluation of Rubber Tapping Workers Using Postural Ergonomic Risk Assessment

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1 Introduction

The rubber tapping is the most demanding skilled agricultural operation in most of the Asian countries like Thailand, Indonesia, Malaysia, India and 90% of the global natural rubber production is from Asia. The musculoskeletal disorders (MSDs) among the rubber tapping workers are high due to cyclic workload, awkward posture, etc. A postural assessment conducted among the rubber tapping workers of Southern Thailand using the Rapid Upper Limb Assessment (RULA) method had reported that one-fourth of the rubber tappers have a RULA score of 4. Hence, a detailed investigation about the body posture of the rubber tappers is necessary and analysis about the change of posture (Meksawi et al. 2012).

A similar study was conducted to evaluate the Carpal Tunnel Syndrome (CTS) among the Thailand rubber tappers using the Boston Carpal Tunnel Syndrome Questionnaire and RULA method. The result found that high wrist flexion and ulnar deviation during repetitive tapping cause CTS. Even though the RULA Score for the wrist flexion was varying between 1 and 3, which is an acceptable posture (Pramchoo et al. 2018a). As an extension to previous research, an ergonomically designed rubber tapping knife is used to improve the CTS among the rubber tappers. However, it is reported that there is no significant difference in wrist flexion among ergonomic and traditional tapping knife users (Pramchoo et al. 2018b).

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Another study was conducted among Srilankan rubber tappers using Quick Exposure Check (QEC) instrument. This research using QEC indicates that shoulder (96.7%), back (94.2) and neck (83.3%) have the highest exposure to ergonomic stress (Stankevitz et al. 2016). Similarly, another study was conducted among the rubber tappers in Malaysia using Nordic Musculoskeletal Questionnaire, and the work reveals that 74.4% of the rubber tappers have a prevalence of MSDs in lower back (Doi et al. 2007; Udom et al. 2016). In addition, few researchers have investigated the prevalence of lower back pain among the Thai rubber tappers and identified that body mass index, primary education and tapping below the knee level are the main reason (Udom et al. 2018). Another poster analysis tool called Ovako Working Posture Analyzing System (OWAS) has been used among the Colombian rubber tapping workers and found that posture score for rubber tapping activities was 4, which calls for an immediate corrective measure (Velásquez et al. 2016).

Most of the ergonomic studies include various posture analysis tool like OWAS, RULA and QEC and some of the literature have further conducted a statistical analysis using various surveys. It is also reported that each of these tools has few limitations. OWAS is a primitive body posture analysis tool, having four digital code for defining various parameters includes back, arms, legs (84 postures) and its corresponding loads (Karhu et al. 1977). The wide range of body postures in OWAS makes misperception to identify accurate body posture and ergonomic stress (Keyserling 1986). RULA is the most useful body poster analysis tool to evaluate work-related upper body disorders (McAtamney and Corlett 1993). It is observed that the rubber tappers having CTS had the RULA score varying from 1 to 3, which is an acceptable level (Pramchoo et al. 2018a). Most of the ergonomics analysis tools are not considering the cyclic work. However, in the present study, the posture analysis of rubber tappers is conducted. Rubber tapping is a monotonous task that involves repetitive work, and each tapper has to cut 300 to 1000 rubber trees every day (Boonphadh 2008). Postural Ergonomic Risk Assessment (PERA), a posture analysis tool which is suitable to evaluate short cyclic work and also help to recognize the source of risk of the workers is applied (Chander and Cavatorta 2017).

The aim of this study is as follows:

- Identify the rubber tapping operations and divide into different work elements.
- Evaluate the percentage of cyclic time and the force required for each task.
- Apply the PERA for posture analysis among the rubber tappers.

2 Materials and Methods

A. *Study Population*

The study was conducted among the rubber tappers in Kottayam, situated in middle Kerala, India. Ten rubber tappers (nine male and one female) were selected for the study. The objective of the study and the data collection methods was informed to all workers, and oral consent was obtained before data were

collected. The inclusion criteria for the selected rubber tappers includes the worker (a) should be a regular tapper, (b) should have a minimum of one-year experience (c) should have an age of 18 years or above.

B. *Postural Ergonomic Risk Assessment (PERA)*

The major evaluation criteria for PERA (Chander and Cavatorta 2017) in rubber tapping process involves.

- Working posture of the rubber tappers
- Force required for tapping
- Duration of each task involved in rubber tapping

The major steps involved for applying PERA are as follows (Chander and Cavatorta 2017);

1. **Work task in rubber tapping**: Based on the distinct posture involved in rubber tapping, divide the work cyclic into different tasks.
2. **Posture for each work task**: Identify the posture of each rubber tapper in each work task
3. **Force applied in each work task**: Calculate the force applied for each work task
4. **Time interval for each work task**: Evaluate the time interval of each work task involved in rubber tapping.
5. **PERA Score**: Categorize the posture, time and force into different risk level.

- Assign the score 1, 2 and 3 for different risk level low, medium and high.
- Calculate each work task score by multiplying each parameter score Work Task Score T_i = (Posture Score)$_i$ × (Force Score)$_i$ × (Duration)$_i$
- Calculate the overall average work cycle score

Overall work cyclic Score A, $= \frac{Ti}{n}$
Where, n = no of work task

(1) *Work task in rubber tapping:* The rubber tapping is the primary step in the rubber harvesting process. Based on the different posture, the cyclic work during the rubber tapping is divided into four tasks and are shown in Figs. 1 and 2.

(2) *Posture for each work task:* The posture of rubber tappers in each work task should be identified and categorized into a low, medium and high risk. Based on the risk level, the score 1, 2 and 3 are assigned to low, medium and high risk, respectively. The detailed body posture and the risk level are tabulated in Table 1.

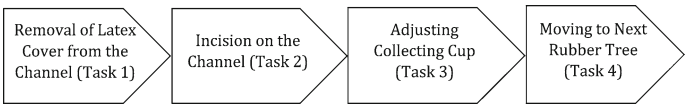

Fig. 1 Flow Chart of various work task in rubber tapping

Fig. 2 Various work task in rubber tapping (**a**) Removal of latex cover from the channel (**b**) Incision on the channel (**c**) Adjusting the collecting cup (**d**) Moving to next rubber tree

(3) *Force applied in each work task:* The physical effort exerted by the rubber tapping workers should be identified and sorted as low, medium and high risk. The physical effort which is not visible like handling of lightweights is included in the low-risk category. The smooth and controlled operations, operations with both hands used, not a heavy operation are encompassed in a medium risk. The

Table 1 Classification of body posture and risk level during rubber tapping (Chander and Cavatorta 2017)

	Trunk-Forward bending	Shoulder—Flexion	Head and neck-Forward bending	Elbow Flexion
Low Risk (Score 1)	0°–20°	0°–20°	0°–25°	0°–20°
Medium Risk (Score 2)	20°–60°	20°–60°	25°–40°	20°–60°
High Risk (Score 3)	>60°	>60°	>40°	>60°

Table 2 Classification of cyclic time during rubber tapping (Chander and Cavatorta 2017)

	Low risk (score 1)	**Medium risk (score 2)**	**High risk (score 3)**
Percentage of the cyclic time for each work task	0%–10%	10%–20%	>20%–10%

Table 3 PERA overall work cycle score (Chander and Cavatorta 2017)

Overall score	Classification of risk level	Recommended actions
$A < 4$	Low Risk	Acceptable; No action is necessary
$4 \leq A \geq 7$	Possible Risk	Further Investigation by a more refined method
$A \geq 7$	High Risk	Not acceptable; Corrective action is necessary

operations which are clearly visible such as vibration from power tools, heavy hammering, impact or shock from heavy machinery are counted in high risks.

(4) *Time interval for each work task:* The time interval required for each work task should be tabulated and the percentage duration of each work task with respect to the cyclic time is to be calculated. The duration of the work is categorized into low, medium and high risk based on the percentage of cyclic time. Each risk level carries a score of 1, 2 and 3 for low, medium and high risk, respectively, and the detailed classification is tabulated in Table 2.

(5) *PERA Score:* The overall work cycle scores are categorized into three levels and listed in Table 3.

3 Result and Discussion

A. *Posture for each work task*

The major body parts involved in the tapping operation are shoulder and elbow, for the first two tasks. The angle measurement for both the cases is more than 60°.

Fig. 3 Posture of each work task in rubber tapping

Table 4 Score of posture for each work task

	TASK 1	TASK 2	TASK 3	TASK 4
SCORE	3	3	3	1

Therefore, task 1 and 2 come under the third category. In task 3, trunk and shoulders are the major body parts involved, and the angle measurement for both the cases are also greater than 60°. So, the score for task 3 was also noted as 3. In task 4, rubber tappers are moving from one tree to the next tree. Hence it was considered as 'low risk' category. Figure 3 shows the posture and angle measurement of each task, and score for each task is tabulated in Table 4.

B. *Force applied in each work task in rubber tapping*

The force required for all tasks expects the second task is considered as low-risk because physical effort exerted in each task is negligible. In task 2, the force required for making an incision in the bark of the rubber tree is calculated using a strain gauge. The force required for a tapping rubber tree is found to be less than 100 N, and the movement of the hand is smooth and controlled during tapping. So, task 2 is considered as medium risk.

III. *Time interval for each work task in rubber tapping*

The time required for each work task is evaluated and the percentage of cyclic time is calculated. Based on the percentage of cyclic time, corresponding score for each task was tabulated and shown in Table 5. The result indicates that the rubber tapper spends most of the time for making incision on the bark of the rubber tree.

IV. *PERA Analysis*

The overall work task scores for each rubber tapper are shown in Table 6. It is found that each rubber tapper has the PERA score of greater than 8, which is recommended for high risk. The score also helps to identify the critical task to be the second task of making incision on the channel among each work tasks.

Table 5 Percentage of cyclic time and corresponding score

Name	Time Durtion (%)				Score			
	Task 1	Task 2	Task 3	Task 4	Task 1	Task 2	Task 3	Task 4
Subject 1	21	48	12	18	3	3	2	2
Subject 2	17	50	13	21	2	3	2	3
Subject 3	20	40	17	23	2	3	2	3
Subject 4	28	41	14	17	3	3	2	2
Subject 5	19	48	13	19	2	3	2	2
Subject 6	18	50	12	21	2	3	2	3
Subject 7	19	52	13	16	2	3	2	2
Subject 8	21	45	17	17	3	3	2	2
Subject 9	16	52	13	19	2	3	2	2
Subject 10	17	48	17	17	2	3	2	2

Table 6 Overall score of the work cycle

Final score						Recommended action
Name	Task 1	Task 2	Task 3	Task 4	Work task score	
Subject 1	9	18	6	2	8.75	Not acceptable, Corrective action is necessary
Subject 2	6	18	6	3	8.25	
Subject 3	6	18	6	3	8.25	
Subject 4	9	18	6	2	8.75	
Subject 5	6	18	6	2	8	
Subject 6	6	18	6	3	8.25	
Subject 7	6	18	6	2	8	
Subject 8	9	18	6	2	8.75	
Subject 9	6	18	6	2	8	
Subject 10	6	18	6	2	8	

4 Conclusion

Rubber tapping is the first and foremost step in natural rubber processing. The rubber tapping involves repetitive motion and contributing high ergonomic risk to various body parts includes elbow, shoulder and trunk. Most of the posture analysis tool like OWAS, RULA, REBA etc. are not considering the cyclic work. PERA is a posture analysis tool to evaluate short cyclic work, which is suitable for the rubber tapping process.

In PERA, the work cycle involved in rubber tapping is divided into different tasks based on the distant postures. The posture of the rubber tappers, the force involved during tapping and duration of each work task is evaluated. Based on the evaluation

criteria, each work task is categoried into “low risk”, “medium risk” and “high risk” and score 1, 2 and 3 are assigned. The overall PERA score is identified as 8 or more for the work cycle, which is corresponding to a level of ‘high risk’. Therefore, the body postures resulted by the tapping work are not acceptable and corrective actions are necessary. Thus the preventative measures are to be implemented in order to prevent bad working condition.

Throughout the research, it is identified that this study has some limitations. First, the rubber tappers selected for this study include workers as well as farmers. Among farmers, they took a long time for tapping, to improve productivity. Second, the posture for each work task by each rubber tappers are varying in different tapping height.

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