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Full Length Research Article

Does Motor Manual Pine Oleoresin Tapping Bring Work-Related Musculoskeletal Disorders Risk to the Tappers? (RoM, REBA, RULA, and OWAS Based Postural Analysis)

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ABSTRACT

Rosin and turpentine oil are commercially developed non-timber forest products generated from pine oleoresin. In Indonesia, the Quarre method is utilized to tap manually or motor-manually (using handheld tapping machines). Handheld tapping machines can greatly boost productivity on the work, but they may also pose serious risks to workers' health. This study aimed to examine the work-related musculoskeletal disorders (WMSDs) risk of motor-manual tapping by using four postural analysis instruments: Natural Range of Motion (RoM), Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), and the Ovako Working Posture Analyzing System (OWAS). In addition to the finding that the use of handheld machines is associated with a high WMSDs risk level, particularly in the work element of renewing the tapping faces, this study demonstrated that RULA is a postural-based risk level instrument with the highest level of sensitivity when being used to assess risk levels in tapping activities involving a great deal of upper limb movements. Despite the widespread use of OWAS for emergency corrective action, this study demonstrates that OWAS has a very low level of sensitivity. For this reason, we stress the importance of using a wide range of instruments for risk assessment to get more accurate results.

1. Introduction

Rosin and turpentine oil are two non-timber forest products (NTFPs) with commercial potential that have undergone extensive commercial development. According to international trade data, Indonesia, China, Brazil, Portugal, and the United States are the world's leading exporters of rosin (OEC 2022), with a total value of USD 1.22 billion (2020 data). Both products are derived from the processing of pine oleoresin. Oleoresin is extracted by tapping the tree's bark. Quarre tapping and the Riil method are methods of tapping that are widely used throughout the world (Cunningham 2012). Among the two tapping methods, tappers in Indonesia seem to prefer the Quarre method due to the basic design of the tapping face, which makes renewing the tapping faces (rewounding) to establish a fresh resin canal simpler.

Locally known as "pethel" or "kadukul", a little hacket is the usual tapping instrument for the Quarre method. Using this manual tapping instrument, a tapper can renew a tapping face to approximately 100 trees per hour (about 3.5 effective hours). In addition to conventional tapping tools, a handheld tapping machine can be used for this renewing work. This gas-powered machine is utilized by pine resin tappers in Java, Indonesia. The usage of these tapping machines built from modified lawn mowers can boost tappers' output by up to 230% (Yovi et al. 2021), allowing them to make more income (Davis 2016; Yovi and Amanda 2019) while satisfying market demand.

Although it has been proven that handheld tapping machines are more efficient than manual tapping tools, gas-powered handheld machines pose a significant Occupational Safety and Health (OSH) risk for the operators (Malinowska-Borowska 2012; Yovi and Yamada 2019). In forestry activities, the gas-powered chainsaw has been the most well-known handheld machine. Chainsaws offer superior portability and versatility at a much lower price and operational cost. Other cutting equipment, such as tree harvesters and feller bunchers, are far more costly to operate than chainsaws. However, handheld chainsaws have been linked to a number of serious health and safety issues in the workplace. Work-related musculoskeletal disorders (WMSDs) (Yovi and Yamada 2019), hearing loss due to exposure to the noise produced by chainsaws (Malinowska-Borowska 2012), and hand-arm vibration syndrome (HAVS) caused by vibration exposure to the operator's hand-arm (Malinowska-Borowska 2012) have been commonly reported among chainsaw users. Since the engines of these two portable gas-powered devices operate similarly, it is not inconceivable that the use of handheld tapping machines will also have negative health impacts on operators.

There has been concern amongst experts about WMSDs. In the United States, WMSDs accounted for around 29–35% of occupational injuries and illnesses from 1992 to 2010, costing USD 2.6 billion per year (Bhattacharya 2014). WMSDs can occur in workers who handle large items, operate in awkward positions, or perform repetitive tasks (Da Costa and Vieira 2010). These three causes of WMSDs can also be seen in pine tapping activities. This suggests that workers using gas-powered handheld tapping machines are at risk for developing WMSDs.

To date, occupational health concerns, particularly WMSDs, have not been the subject of many investigations on tapping activities utilizing handheld tapping machines. Whereas it is important to consider the potential occupational health risks associated with utilizing handheld tapping machines when making decisions for tapping management, it is equally important to consider the benefits of utilizing such equipment, such as increased productivity. This potential risk information can be utilized as a basis for corrective action to lower the risk of WMSDs in workers, thereby minimizing possible losses for workers and enterprises. Therefore, the goal of this study was to determine (utilizing widely used measurement instruments: the RoM, REBA, RULA, and OWAS) the risk of WMSDs associated with the use of gas-powered handheld tapping devices. In addition, since the four instruments have slightly different approaches, this study also sought to figure out the best instrument for postural analysis in pine tapping activities so that future researchers can use this information to select the appropriate instrument for conducting postural analysis in other activities with comparable characteristics.

2. Methods

The data in this study are March 2020 video recordings of nine working days of tapping in a pine forest in Sukabumi, Indonesia. Approximately 2,000 trees were tapped in the video recordings. The work postures analyzed in this study were observed from selected work cycles (performed by 3 tappers out of 8 active tappers in the study site) that were clear enough to allow detailed observations. A preliminary analysis indicated that the average cycle time was around 20 seconds per tapping face, which led us to conclude that 90 cycles adequately represented the entire population (Niebel and Freivalds 2014). A field visit in October 2022 confirmed that there were no modifications to the tapping method. This indicates that the work postures depicted in the video clip reflect the current work postures for pine tapping. The handheld tapping equipment used weighed 14 kg (gross).

The criteria that can be used to select the work postures for further analysis include those that are held for the longest duration, appear to be the posture with the highest risk, or are related with the greatest load (David 2005; Joshi and Deshpande 2019; Roman-Liu 2014). The second criterion is the position that is repeated most frequently. According to interviews and observations, the position required the highest amount of muscle activity and was known to produce discomfort was the one that was repeated most frequently. The final criterion for selection is an awkward, unstable, and excessive posture, particularly in situations where great power is required. In this study, we employed two criteria: the posture that appears to pose the greatest risk, as assessed by the RoM concept, and the most often repeated postures, as determined by observation data.

The postures evaluated should represent each element of work in a single tapping cycle. To determine the work element, we treated the tapping of a single tree as one tapping cycle. Observations on the field revealed that there was one work element that only emerged at specific moments (for example, at the beginning of the cycle on one day of observation), but the movements within this work element were crucial. This work element involves installing/positioning the machine in the back, which is known to involve strenuous movements that may cause WMSDs. Even though there were three work elements in one tapping cycle, namely walking, cleaning the work area, and making a new wound (rewounding, renewing of the tapping faces), we added postures from the "positioning the machine in the back" work element for analysis. The work postures for each element were studied in great detail using recordings of selected 90 work cycles that were clear enough to allow detailed observations.

2.1. Selection of Work Postures using the Concept of Natural Range of Motion (RoM)

Generally, the range of motion (RoM) of a human body segment, i.e., the range of movement that is still achievable for a joint under normal conditions, may vary between individuals. There are a variety of normal standard ranges now in use. One is the natural RoM, which was subsequently collated by Openshaw and Taylor (2006). According to this approach, the joint range of motion is divided into four zones:

1. Zone 0 (green zone), in which the majority of motions are advised, places low stress on the muscles and joints.
2. Zone 1 (the yellow zone), a recommended movement zone, offers better joint mobility than zone 0.
3. Zone 2 (the red zone), where there are numerous severe body positions, muscle and joint tension are increased.
4. Zone 3 (beyond the red zone), which contains numerous severe body positions, should be avoided whenever feasible, particularly when carrying big objects or doing repetitive activities.

2.2. Postural Analysis of the Selected Postures

Postural analysis is one of the methods that can be used to assess the risk of WMSDs in a particular activity. The analysis of posture can be conducted either subjectively or objectively. Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), and Ovako Working Posture Analyzing System (OWAS) are widely recognized examples of objective qualitative postural analysis (Lowe et al. 2019; Roman-Liu 2014;). Despite the assumption that the anthropometric size of the worker has no effect on the risk estimation results, all three instruments are acknowledged as providing estimates that are deemed accurate. Each instrument takes a different approach to evaluating the level of risk, and as a result, each instrument has its limitations that manifest in the estimation results (Joshi and Deshpande 2021; Kee 2022). This study used all three instruments to provide a more thorough risk assessment. However, it should be noted that REBA, RULA, and OWAS are risk assessment instruments for WMSDs that do not account for the influence of duration, vibration, noise, and other ambient variables on WMSDs' risk levels (Chiasson et al. 2012; Takala et al. 2010).

2.3. Rapid Entire Body Assessment (REBA)

REBA is a work posture assessment method that considers all body components (Hignett and McAtamney 2000). In REBA, postures are evaluated based on two primary body groups, A and B. Group A includes the neck, the trunk, and the legs. Group B includes the upper arm, the lower arm, and the wrist. Load, coupling, and activity parameters are all taken into account by REBA. Frequency and presence/absence of repetitive movements are also included in the activity factor (both minor and major movements). The scoring system is divided into five "action levels", each of which indicates the investigation's urgency. The scores for the five levels of action are as follows: 1 = negligible risk; 2–3 = low risks, change might be required; 4-7 = medium risk, requiring further investigation and implementation of change soon; 8-10 = high risk, requiring investigation soon and implement change; 11+ = very high risk, implement change.

2.5. Rapid Upper Limb Assessment (RULA)

RULA is a method designed in the field of ergonomics to explore and evaluate work postures, with a focus on upper body assessment (McAtamney and Corlett 1993). The examined postures were classified into two major categories, A and B. Group A consisted of the upper arm, the lower arm, and the wrist. Group B includes the head, trunk, and legs. Although RULA also considers the legs, just like REBA, scoring depends on whether or not the legs are supported. In RULA analysis, load factor and muscle use are corrective factors. Unlike REBA, RULA's score system is divided into four action levels that indicate the urgency of the investigation. The four levels of action are as follows: score 1-2 = acceptable posture (if it is not maintained for an extended period); score 3-4 = low risk, further investigation is required and changes may be necessary; score 5 or 6 = medium risk, investigation and changes are required soon; score 6+ = extremely high risk, investigation and changes are required immediately.

2.6. Ovako Working Posture Analyzing System (OWAS)

OWAS, like REBA and RULA, is a method for examining and analyzing awkward work postures that might lead to MSDs (Karhu et al. 1981). OWAS based its evaluation on the movement of the back, arms, and legs, as well as the weight of the load carried by the worker. The outcome of the OWAS study is a score representing the posture of each body part of the worker. Each OWAS final score is interpreted as follows: 1 = no action is required; 2 = corrective actions are required in the near future; 3 = corrective actions should be completed as soon as feasible; and 4 = corrective actions for improvement are required immediately. The OWAS method, like REBA and RULA, can rapidly identify work postures with the potential to cause WMSDs.

3. Results and Discussion

3.1. Results

Observation of the nine selected work cycles identified eight work postures in the walking work element, nine work postures in the machine installment work element, five work postures in the understory cleaning work element, and eighteen work postures in the renewing tapping face work element. **Table 1** presents the postural variations identified for each work element. In addition, based on the results of the RoM assessment of the 40 identified postures, we selected 12 postures (**Table 2**) that were further assessed using the REBA, RULA, and OWAS instruments.

Table 3 presents the angles at various body segments while tapping pine with a handheld tapping machine in the 12 selected postures. **Table 4** displays the final results from the REBA, RULA, and OWAS analyses.

3.2. Discussion

The tapping of pine resin involves at least four components, including walking, installing the tapping machine, clearing the undergrowth, and renewing the tapping face. As tapping is a dynamic activity, different work postures were found in a work element. As noted previously, the analysis was limited to those work postures that appeared to pose the most danger (as determined by the RoM concept) and were the most often repeated. Therefore, the improvement is directly aimed at work postures that have a high risk of WMSDs.

In general, the work postures formed in each work element are associated with various degrees of risk; yet, the REBA, RULA, and OWAS instruments interpreted the risk level categories differently. In the walking work position, OWAS determined that all selected walking postures (W1, W4, and W7) were acceptable. However, REBA and RULA determined that these postures posed a medium risk.

In the machine installment, OWAS detected posture S7 as requiring corrective measures (in the future) during the work part of installing the machine but did not recommend any modifications to postures S3 and S6. The forward bending position of the trunk in S7 increases muscle stress, and therefore the work will necessitate exceptional muscular endurance. This circumstance will result in increased muscular loading and stretching, which can lead to musculoskeletal issues and raise workers' workloads (Laithaisong et al. 2022). This OWAS reading was distinct from the REBA and RULA readings, particularly with regard to the S6 posture. REBA rated S6, a standing position with extreme flexion at the right shoulder and elbow, as "high risk", but RULA assessed it as "extremely high risk". RULA's assessment weighting of the upper body (in this case, the neck and arms) contributes to the difference in risk level. The consistency of RULA's weighting on the upper limb is also can be seen in S3 evaluation outcomes. In posture S3, in which the right and left legs were extremely flexed, RULA is not as sensitive as REBA. In this S3, RULA rated the risk level as low risk, while REBA rated it as medium risk (hence REBA recommends

Table 1. The natural Range of Motion analysis results: the zonation of 40 work postures identified through observation on 90 work cycles

Postures	Neck		Trunk		Shoulder				Elbow		Wrist				Hip		Knee		Ankle			
					R		L		R	L	R		L		R	L	R	L	R		L	
	F	E	F	E	F	E	F	E	F	F	F	E	F	E	F	F	F	F	F	E	F	E
W1	19		22			21		3	53	78	39			5	44	13	42	33	10		2	
W2*	20		4			16		6	33	91		14		5	8	17	46	40		2	27	
W3	10		26			18	39		100	52	14			5	69	12	42	7		1	21	
W4*	4			2		2	13		91	28	6		7		0	19	5	81	2		14	
W5	9		40		12		35		61	7	3			5	32	91	33	62	18		4	
W6	0		16			8	2		69	40		12	3		30	19	16	17	0		14	
W7*		6	7			4		5	112	53		27	0		0	34	0	54	19		16	
W8		12		9	35		16		100	122		12		8	23	12	77	18		14		3
S1	39		28		17			14	17	74		10		8	32	39	10	5	4			5
S2		7	5			12		5	78	64		8		20	3	4	1	0	2		1	
S3*	40		0		0		34		111	13	5			13	71	66	163	156	31		21	
S4	27		83		53		72		35	50		7		21	88	93	6	0	1			10
S5	30		39		36		40		32	24		2		8	53	46	4	0		9		7
S6*		14		3	100			3	148	90	5		11		0	0	13	22	9		19	
S7*		6	92		52		75		60	10	7			16	108	76	6	5		10	11	
S8	6		43		25		13		53	48	15		0		39	37	0	10		13	1	
S9*	15		0		17		21		110	88	0			9	4	11	23	0		24		40
C1*	8		5			40	33		72	47		29		11	8	8	6	6	3		3	
C2*	4		17			30	37		101	17		4	1		34	1	17	4	1		2	
C3	6		5			8	20		83	35		5	13		7	8	1	4		3		5
C4	7		19		22			4	78	87		4	0		15	2	6	2		0		2
C5*	6		3		2			12	90	47	12			25	18	3	16	3	1			2
R1	17		14			4	29		83	79	12		2		23	13	50	3		14	4	
R2	10		25		16		56		68	45		2		10	46	27	21	0	15			2
R3*		63		1	155		154		9	22	34			6	0	0	18	7		17		15
R4	10		35		8		52		50	54		15	14		11	42	8	0		33		5
R5	3			1	0		48		82	54	21		16		0	31	8	58		5	25	
R6		19	4		25		102		78	33	12			26	0	0	4	13	1		17	
R7	11		35		9		58		59	9		3	0		51	75	11	41	0			3
R8*		3		23	31		86		84	28		6		3	21	2	2	23	9			4
R9	8		22			25	39		87	19		5		10	31	14	13	1	1		1	
R10	10		2			10	47		82	8		0		5	14	3	12	1		4		1
R11		5		14	27		93		103	29		2		7	13	14	7	16		2		5
R12		27		18	141		87		17	92		28		14	32	26	1	16	14			1
R13		3		4	52		16		70	85		22		0	4	2	9	51	1			32
R14		17		11	120		67		22	103		23		12	14	19	4	11	12			4
R15*	9		0		12		4		69	47		9		0	76	5	107	121	29			2
R16		4	7		10			6	66	45	7		7		74	7	90	55	21			22

Notes: * selected postures; number is in degree (°). W= walking, S= installing the machine on the back, C= cleaning understorey, R: renewing.
R: right, L: left, F: flexion, E: extension, : Zone 0, : Zone 1, : Zone 2, : Zone 3

posture changes). This finding is in line with the study of Joshi and Deshpande (2021) that stated the occurrence of sensitive and insensitive zones in the RULA.

Table 2: Selected postures that represent work postures in pine tapping activities using a handheld tapping machine

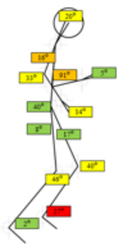
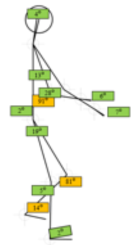
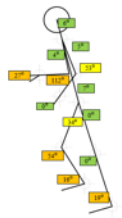
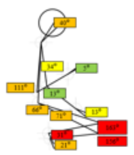
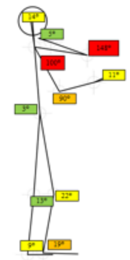
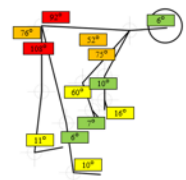
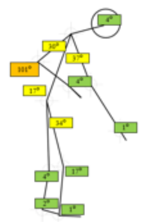
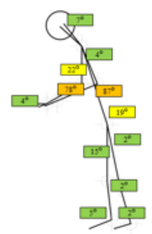
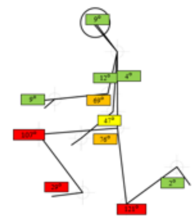
	Posture 1	**Posture 2**	**Posture 3**
Walking	W1 	W4 	W7 
Installing the machine	S3 	S6 	S7 
Cleaning understorey	C1 	C2 	C5 
Renewing the tapping face	R3 	R8 	R15 

Notes: W= walking, S= installing the machine on the back, C= cleaning understorey, R: renewing.

The difference in other readings was in posture C1. The lowest risk level resulted from the OWAS reading (no action required), followed by REBA (medium risk). However, RULA gives a risk level reading of "very high risk" on the right body, which based on the RoM analysis results is in zone 3 (extreme extension) on the right shoulder.

OWAS's insensitivity to upper body movement is also evident in the R3 posture reading. Owas identified the posture of standing upright with both hands in the flexion position with angles of 155 and 154 degrees (**Table 1** and **Table 2**) as no risk (no action required). The insensitivity of OWAS has been a concern, and the findings of this study were in line with the previous study carried out by Hellig et al. (2019), although in this study, Hellig et al. also found that OWAS had a stronger correlation with biomechanics measures, including the L5/S1 compressive forces. In contrast to the OWAS results, the REBA and RULA readings classified this position as high-risk (REBA) and extremely high-risk (RULA). As evidenced by the R8 assessment results, OWAS demonstrated a high degree of sensitivity when evaluating postures involving severe trunk extension (**Tables 1 and 2**). These measurements are comparable to those of RULA (right and left torso) and REBA (left torso) (**Table 1**). In the reading of the right side of the body's risk level, the REBA score indicated a moderate-risk posture. This is because REBA believes the angle generated by the right upper arm is not excessive.

Table 3. Angles at various body segments in selected postures

	Posture 1	**Posture 2**	**Posture 3**
Walking	W1 	W4 	W7 
Installing the machine	S3 	S6 	S7 
Cleaning understorey	C1 	C2 	C5 
Renewing the tapping face	R3 	R8 	R15 

Notes: W= walking, S= installing the machine on the back, C= cleaning understorey, R: renewing.

This study confirmed that RULA has a higher measuring sensitivity than REBA and OWAS. RULA is more sensitive than OWAS, as demonstrated by its readings at W1, W4, W7, S3, S6, S7, C1, C2, C5, R3, R8, and R15. This result validated the previous results of Nver-Okan et al. (2017)

and Yayli and Çalişkan (2019). Further, the S6, C1, R3, and R8 results demonstrate that RULA is more sensitive than REBA. This finding validated the research undertaken by Kee (2022).

Table 4. Final scores on REBA, RULA, and OWAS analysis of selected postures

Task	Instrument	Posture 1*		Posture 2		Posture 3	
Walking		W1		W4		W7	
	REBA	R = 4	L = 4	R = 3	L = 6	R = 4	L = 6
	RULA	R = 6	L = 6	R = 5	L = 5	R = 6	L = 6
	OWAS	1		1		1	
Installing the machine		S3		S6		S7	
	REBA	R = 4	L = 4	R = 8	L = 4	R = 5	L = 6
	RULA	R = 4	L = 4	R = 7	L = 7	R = 6	L = 6
	OWAS	1		1		2	
Clearing understorey		C1		C2		C5	
	REBA	R = 4	L = 4	R = 4	L = 4	R = 3	L = 4
	RULA	R = 7	L = 6	R = 6	L = 6	R = 6	L = 6
	OWAS	1		2		1	
Rewounding		R3		R8		R15	
	REBA	R = 8	L = 8	R = 6	L = 8	R = 4	L = 4
	RULA	R = 7	L = 7	R = 7	L = 7	R = 5	L = 5
	OWAS	1		3		1	

REBA color coding**:
1 Acceptable posture; 2-3 Low risk; 4-7 Medium risk; 8-10 High risk; 11-15 Very high risk

RULA color coding**:
1 Acceptable posture; 3-4 Low risk; 5-6 Medium risk; 6+ Very high risk

OWAS color coding**:
1 No action required; 2 Corrective actions required in the near future

3 Corrective actions should be done as soon as possible; 4 Corrective action for improvement required immediately

Notes: *R = right, L = left. **Colors were chosen only to facilitate the reading of the table and were determined based on the researcher's interpretation of the level of the need for change/improvement. W= walking, S= installing the machine on the back, C= cleaning understorey, R: renewing.

Regardless of the differences in risk level readings across the three instruments, it can be inferred that renewing the tapping face is a work element that demands a greater degree of physical disruption than other postures. Given that renewing is an element of work that is present in every cycle, renewing tapping face postures requires improvement. Therefore, ergonomic measures are required to lower the risk of WMSD associated with high-risk work positions.

Workplace and job characteristics, as well as whether the investigation is theoretical or practical in nature, influence the selection of methods employed to assess the potential for WMSDs (David 2005; Li and Buckle 1999). OSHA advises hazard control strategies for preventing WMSDs, and among them are the engineering control (e.g., design of work stations, work procedures, and tools) and the administrative/management approach (e.g., work management and organization) (OSHA 2022). The concept is to minimize the angle of body segments as underlined by Niebel and Freivalds (1999) as one method for reducing the likelihood of WMSDs. The engineering control can be accomplished by designing tools that enable workers/tappers to work in neutral positions, e.g., lowering the degree of the arm, neck, and trunk muscle movements. Extreme movement (in both flexion and extension) in certain body segments can be reduced by determining the maximum height of tapping faces that may still be reached without difficulty. In situations when high renewing points cannot be avoided (e.g., due to the pursuit of production goals), extreme flexion and extension can be avoided by keeping workers in an upright position with low neck extension and minimal upper arm flexion. Providing steps or limiting the height of the tapping faces are also appropriate strategies in the domain of engineering control.

As indicated earlier, the REBA, RULA, and OWAS assessments exclude other elements that must be addressed when measuring the improvement of work posture in tapping activities utilizing handheld tapping machines. These factors include: exertion frequency per cycle, load (Hasegawa et al. 2018), recommended weight limit (RWL) (Yovi and Awaliyah 2021), compression and shear forces acting on the lower back (Yovi and Awaliyah 2021), the amount of energy expended while performing work, vibration and noise exposure received by the tappers (Malinowska-Borowska et al. 2012; Yovi and Suryaningsih 2011), and other external physical factors (e.g., air temperature and humidity) (Kjellstrom et al. 2016; Oppermann et al. 2021).

In this study, the handheld tapping machine weighed 14 kg, which increased the risk of WMSDs. Long-term exposure of the body to heavy weights causes intense compression and shear pressures that might harm the lower back (Yovi and Awaliyah 2021). In addition, the repeat of the motion required to install the machine in the back of the tappers must be diminished. Frequent problems with the machine necessitate that tappers periodically remove the unit to start it up or make repairs and then reinstall it. If the machine does not turn off frequently, then the work element of installing the machine in the back does not need to be performed frequently, and the tapper does not need to be exposed to a very high-risk level (**Table 4**). This excessive muscular action may result in low back pain (Yovi and Awaliyah 2021), which can negatively impact worker productivity (Dutmer et al. 2019; Karwowski and Marras 2003) and quality of life (Husky et al. 2018; Kahraman et al. 2016). Efforts that can be made to lessen the risk caused by the load (machine's weight) include decreasing the machine's weight to the limit that workers can tolerate based on their work activities. This limit, also known as RWL, must be calculated in the subsequent investigation.

4. Conclusions

This study demonstrates that tapping pine with a handheld tapping machine poses health risks to workers. It was discovered that the risk of WMSDs was greatest during the process of renewing tapping faces. In the postural analysis of pine tapping work using a handheld tapping machine, RULA has the highest level of sensitivity when compared to RoM, REBA, and OWAS. OWAS is the most insensitive of the four instruments. A risk assessment of WMSDs using only one type of instrument may produce inaccurate results due to the varying sensitivities of the various instruments.

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