Ergonomic investigation of workers in tea factories using REBA and OWAS methods – case study: (Langroud region, Guilan, Iran)

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Abstract: Work-related Musculoskeletal Disorders (WMSDs) are a leading cause of disability, work time loss and economic loss in both industrialized and developing countries. WMSDs include muscles, bones, joints, nerves and blood vessel disorders. According to the studies done by some researchers, the lack of harmony between technology and the technology users in workplace can degrade the product quality and increase the injuries. In the present study, an ergonomic investigation was conducted and the position and posture of the workers of tea factories were evaluated. REBA and OWAS methods were used for analyzing the postures. The energy expenditure of workers was calculated by heart rate monitoring. In this study, 6 tea factories were considered and totally 48 workers were assessed. Production units of tea factories were classified into three categories, including withering unit, curling and oxidation unit and drying and grading unit. Results showed that 75 % of used postures by the workers of tea factories need corrective measurements. Also, based on the OWAS results, 34% of used postures had high and very high risk levels. Worker' back flexion, placing one arm above shoulder and standing on one leg are the most important positions in tea factories, which lead to musculoskeletal disorders. Thus, the corrective measurements should be done to reduce them. Withering unit was the most energy-consuming unit for workers. The average of energy expenditure of tea factories workers was 21.843 kJ min^{-1}.

Keywords: ergonomic, tea factory, heart rate, withering, grading, curling

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1 Introduction

Nowadays, Work-related Musculoskeletal Disorders (WMSDs) are one of the most common occupational injuries and a leading cause of disability, work time loss and economic loss in both industrialized and developing countries (Choobineh et al., 2009; Da Costa and Vieira 2010; Dianat et al., 2015; David et al., 2008). Approximately, half of the world's entire workforce is employed in agriculture sector (Fathallah, 2010). Most of the evidences, especially in the developing countries, show that lack of harmony between technology and the technology users in workplace can degrade the product quality and increase the injuries. Prevention efforts have been focused on the identification of problem exposures by established relationship between musculoskeletal disorders and job physical demands (Jones and Kumar, 2007). Nowadays, workplace interventions are considered to reduce WMSDs by researchers (Oakman et al., 2014). Generally, WMSDs include muscles, bones, joints, nerves and blood vessel disorders.

Awkward posture during work is one of the most important risk factors of musculoskeletal disorders and is considered as the basis of the assessment in the most authentic methods of the musculoskeletal disorders risk assessing. Some standard methods have been given for awkward posture assessing:

1- RULA (Rapid Upper Limb Assessment)

2- OWAS (Ovako Working Posture Analyzing System)

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3- NORDIC questionnaire

4- REBA (Rapid Entire Body Assessment)

5- QEC (Quick Exposure Check)

Each measurement and observation gives some information about body posture (Levanon et al., 2014). In these methods, the frequency of extreme joint motion and magnitude of joint angle are considered to analyze the awkward postures (Dartt et al., 2009). Generally, ergonomics has a multi-disciplinary nature and plays an important role in the prevention of WMSDs (Jafry and O'Neil, 2000).

The objective of this study was to evaluate the position and posture of the workers of tea factories in Guilan province. This study was conducted based on the REBA and OWAS standard methods. Also energy expenditure of workers was calculated by heart rate monitoring.

REBA has been designed for assessing the jobs that have both dynamic and static postures and also is used in a workplace that there are large changes in worker postures. OWAS was used in a steel manufacturing plant in Finland called Ovako Oy for the first time in 1970s. This method is easy and reliable for analysts and in addition to identifying problems; it can prioritize the need for reforms (Chiasson et al., 2015; Brouijn et al., 1998).

Choobineh et al. (2009) investigated musculoskeletal problems among workers of a sugar-producing factory in Iran. 116 workers were randomly selected from production units and investigated in this study. QEC was used to assess work-related postures. Results showed that the level exposure to MSD risks was high and very high, so corrective measures for reducing risk level was essential.

Earle-Richardson et al. (2005) gave an ergonomic method to reduce back strain among apple workers. The Case study was applied among New York State workers. 14 apple workers wore a hip belt intervention and then were interviewed and measured. Results showed that 79% of workers preferred the modified bag, 71.4% felt a difference in the back, neck and shoulder. 64.3% said that they couldn't work normally with this belt. Work sampling demonstrated this intervention hadn't affected work productivity. Ojha and Kwatra (2012) conducted an ergonomic study on musculoskeletal disorders due to manual rice transplanting. 20 workers were randomly selected for this study. Body map and NORDIC questionnaire were used to analyze data. Most of the workers were suffering from pain in neck, shoulder, upper and lower back. Mechanical rice transplanting could be considered as a most promising solution.

An ergonomic evaluation was conducted by Jyotsna et al. (2005) for rural women in wheat harvesting activity. 20 women in two age-group (25-35 and 35-45 years) were randomly selected. Results showed that women spent 8 hours in wheat harvesting activity and 2 hours in bundling activity per day. The heart rate was also measured in this study and the average of that was 121.5 beats min^{-1} and increased up to 126.7 beats min^{-1} at the end of the activity. The related energy expenditure was calculated as 10.5 kJ min^{-1}, which reached to 11.2 kJ min^{-1} at the end of the activity.

Choobineh et al. (2004) gave an ergonomic method in carpet mending operation. 72 menders were selected and interviewed. Among them, pain in knees, back and shoulders were more than other body parts. RULA technique was used to assess the work-related postures. The new workplace was evaluated good or very good in 57% of cases. Hu et al. (2011) used a virtual environment in order to predict real-world ergonomic measurements. They studied the relationship between ergonomic measurements in virtual environment and real environment for some drilling tasks. 30 workers were studied. Five assessment indices (three objectives and two subjects) were used for this study. Results showed that for two of the five indices, there was a linear correlation between virtual environment and real environment. Arip Wahyudi et al. (2015) analyzed work postures related to the manual material handling using OWAS method. The Nordic Body Map questionnaire was also used for analyzing work postures. Results showed that 42%, 6%, 26%, and 26% of activities were at category 1, category 2, category 3, and category 4, respectively.

2 Materials and methods

This study was conducted during 2014 spring and summer in Langroud city in Guilan province, Iran. In this study, 6 tea factories were considered and totally 48

workers were assessed. Production units of tea factories were classified into three categories. There were 12 workers (2 workers from each factory) in withering unit, 24 workers (4 workers from each factory) in curling and oxidation unit, and 12 workers (2 workers from each factory) in drying and grading unit, in the study. Photography technique was used to record the different postures in each workstation.

2.1 REBA

There are both dynamic and static postures and different forms of body position in the production units of tea factories. Thus, REBA was used for analyzing the postures. REBA is designed by McAtamny and Hignett in order to assess the postures in the activities with various postures in 1995. In this method, different parts of body have been classified in two groups. Group A is related to the trunk, neck and legs with 72 posture combinations. Table 1 shows codes of the group A and Table 2 shows the posture combinations scores. Group B is related to the upper arms, lower arms and wrists with 36 posture combinations. Table 3 and Table 4 show group B codes and posture combinations scores, respectively. Also load or force is considered. Its related codes have been given in Table 5 (Hignett and McAtamney, 2000).

Also the workers heart rate was measured and their energy expenditure was calculated with Equation 1 that has been given by (Keytel et al., 2005):

$$EE = \text{gender} \times (-55.0969 + 0.6309 \times \text{heart rate} + 0.1988 \times \text{weight} + 0.2017 \times \text{age}) + (1-\text{gender}) \times (-20.4022 + 0.4472 \times \text{heart rate} - 0.1263 \times \text{weight} + 0.074 \times \text{age}) \quad (1)$$

where, gender = 1 for males and 0 for females. EE is the acronym of Energy Expenditure.

Table 1 Group A specifications and scores

Body part	Movement	Score	Change score
Trunk	Upright	1	+1 if twisting or side flexed
	0º-20º flexion or extension	2	
	20º-60º flexion	3	
	>20º extension		
	>60º flexion	4	
Neck	0º-20º flexion	1	+1 if twisting or side flexed
	>20º flexion or in extension	2	
Legs	Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30º and 60º flexion +2 if knee(s) are >60º flexion (Not for sitting)
	Unilateral weight bearing Feather weight bearing or an unstable posture	2	

Table 2 Group B specifications and scores

Body part	Movement	Score	Change score
Upper arms	20º extension and 20º flexion	1	+1 if arm is abducted or rotated +1 if shoulder is raised -1 if leaning, supporting weight of arm or if posture is gravity assisted
	>20º extension	2	
	20º-45º flexion		
	45º-90º flexion	3	
	>90º flexion	4	
Lower arms	60º-100º flexion	1	-
	<60º flexion or >100º flexion	2	
Wrists	0º - 15º flexion or extension	1	+1 if wrist is deviated or twisted
	>15º flexion or extension	2	

Table 3 Exposure scores related to the Group A body parts in REBA

Trunk		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
1		2	2	3	4	2	2	3	4	3	3	5	6
2		2	3	4	5	3	4	5	6	4	5	6	7
3		2	4	5	6	4	5	6	7	5	6	7	8
4		3	5	6	7	5	6	7	8	6	7	8	9
5		4	6	7	8	6	7	8	9	7	8	9	9

Table 4 Exposure scores related to the Group B body part in REBA

Upper arm		Lower arm					
		1			2		
	Wrist	1	2	3	1	2	3
1		1	2	2	1	2	3
2		1	2	3	2	3	4
3		3	4	5	4	5	5
4		4	5	5	5	6	7
5		6	7	8	7	8	8
6		7	8	8	8	9	9

Table 5 Load or force

0	1	2	+1
<5 kg	5-10 kg	>5 kg	Shock or rapid buildup of force

2.2 OWAS

OWAS was used in a steel manufacturing plant in Finland called Ovako Oy for first time in 1970s (Kant et al., 1990). This method is easy and reliable for analysts and in addition to identifying problems; it can prioritize the need for reforms (Chiasson et al., 2015; Brouijn et al., 1998).

In this method, work-related postures including back, arms and legs and also load are assessed. Table 6 shows these postures.

Table 6 Classified postures of body parts in OWAS

Body part	Posture
Back	Straight
	Bent
	Twisted
	Bent and Twisted
Arms	Both below shoulder
	One above shoulder
	Both above shoulder
Legs	Sitting
	Standing on two legs
	Standing on one leg
	Standing on two bent knees
	Standing on one bent knee
	Kneeling
	Walking

In order to score and analyze the work-related postures in each work phase, Winowas software was used. Postures of tea factories workers were analyzed by examining the photos of workers postures in order to determine the scores of each body part (back, arms and legs) postures and applied load in Winowas software (Arip Wahyudi et al., 2015; Bruijn et al., 1997).

3 Results and discussion

3.1 REBA results

According to the results that were obtained from REBA, 75% of used postures by the workers of tea factories were in the 4 to 7 score level. It means that their level exposure to risk is medium and corrective measurements are necessary. The postures in the 2 to 3 score level with low level exposure to risk and the postures in the 8 to 10 score level with high level exposure to risk were allocated 12% of all postures. The corrective measurements may be necessary and necessary soon. Just 5 postures (0.53% of all postures) were in 11 to 15 score level. These postures with very high level exposure to risk were related to the curling and oxidation unit and corrective measurements is necessary now. Percentage of postures with medium level exposure to risk and scores between 4 to 7, was 74%, 79% and 67% respectively for withering, curling and oxidation, drying and grading units Table 7.

Table 7 Score of work-related postures and their action level in REBA

Production units	Final score									
	1		2 to 3		4 to 7		8 to 10		11 to 15	
	Num*	%	Num*	%	Num*	%	Num*	%	Num*	%
Withering	0	0	24	10	178	74.2	38	15.8	0	0
Curling and oxidation	0	0	23	4.79	381	79.4	71	14.8	5	1.05
Drying and grading	8	3.33	67	27.9	161	67.1	4	1.68	0	0
Total	8	0.83	114	11.9	720	75	113	11.8	5	0.53

Num*: Number of observations.

3.2 OWAS Results

Results showed that 37% of all used postures in the withering operation were in the group 1 that no necessary corrective measurement was needed. Also in this stage, 24% and 3% of postures were in the group 3 and 4, respectively, that the priority of corrective measurements is necessary soon and necessary now, respectively.

In the curling and oxidation unit, 42% and 32% of postures were in the group 2 and 3, respectively. Corrective measurements are necessary for the majority of postures, according to the results. For 10% of postures, corrective measurements are needed immediately.

In the drying and grading unit, the postures with medium and high risk level, each allocated 25% of postures. The majority of postures in this stage didn't need corrective measurements.

Totally, 30%, 36%, 28% and 6% of all used postures in tea factories, had low, medium, high and very high level risk, respectively. In order to reduce the physical damages on workers, corrective measurements and workplace modification are necessary soon and necessary NOW for postures with high and very high level risk, respectively Table 8.

Recommendation for actions results that were obtained from Winowas software, have been shown in following figures for withering unit (Figure 1), curling

and oxidation units (Figure 2), drying and grading units (Figure 3). Recommendation for whole work units have been given in Figure 4.

Table 8 Score of work-related postures and their action level in OWAS

Production units	Final score							
	Categ. 1		Categ. 2		Categ. 3		Categ. 4	
	Num*	%	Num*	%	Num*	%	Num*	%
Withering	89	37	86	36	57	24	8	3
Curling and oxidation	77	16	202	42	153	32	48	10
Drying and grading	118	49	60	25	60	25	2	1
Total	288	30	346	36	269	28	57	6

Num*: Number of observations, Categ: Category.

According to these results, the most corrective actions for back in the curling and oxidation stage should be done in order to reduce the back flexion of workers. These postures allocated 78% of all back-related postures (Figure 2). In the withering stage, postures related to the back flexion, one arm above shoulder and standing on one leg need corrective measurements in close future (Figure 1). In the drying and grading stage, corrective measurements for postures that are related to back flexion and standing on two bent knees are necessary (Figure 3). Totally, corrective measurements should be done in order to reduce workers back flexion, modify the situations that result in placing one arm above shoulder and also situations that cause to stand on one leg (Figure 4).

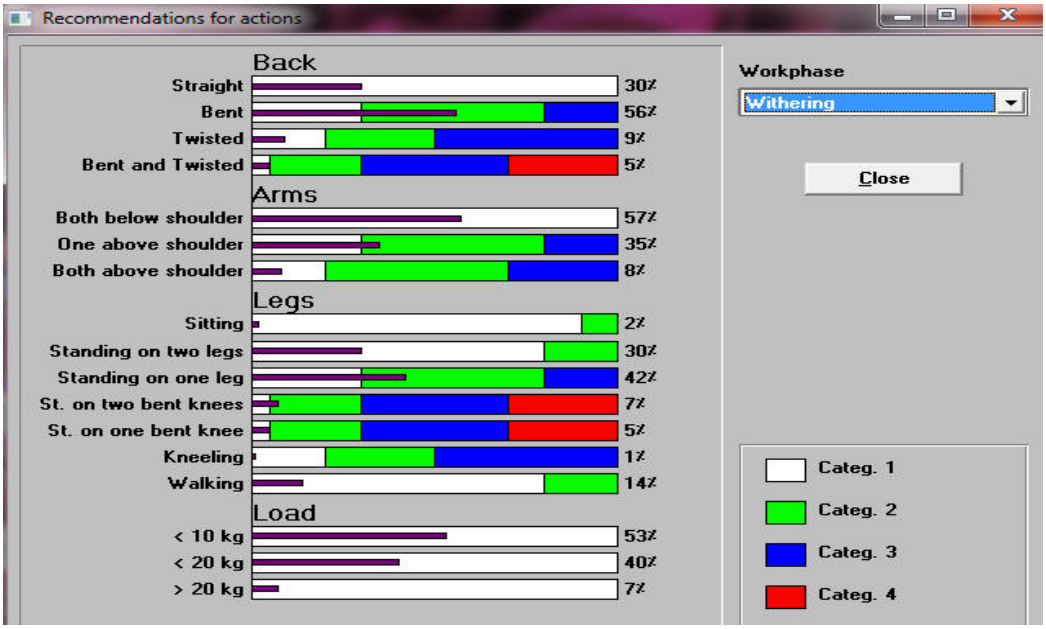

Figure 1 Recommendation for actions in Withering work phase

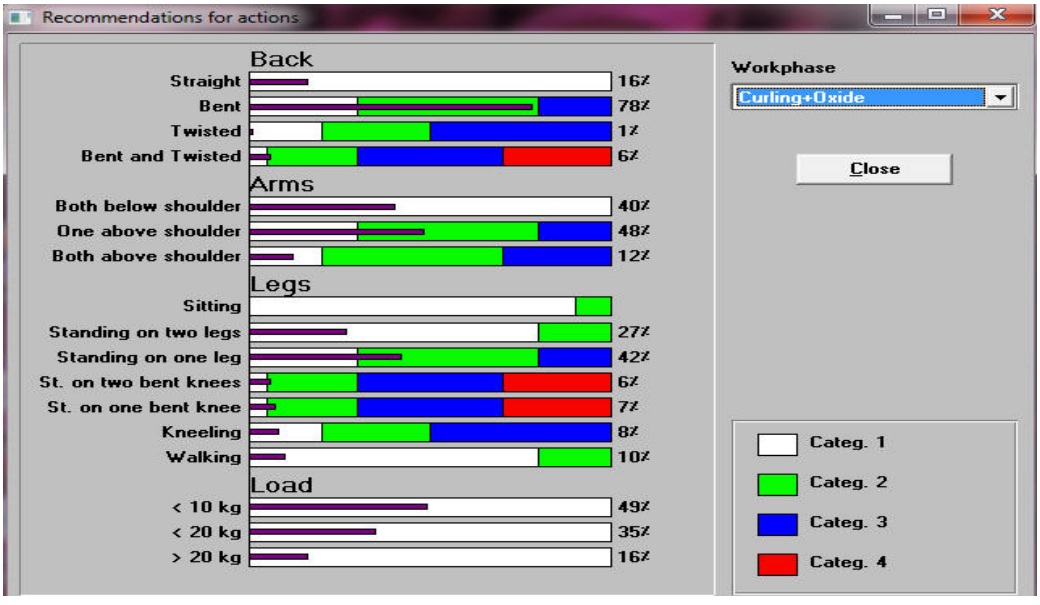

Figure 2 Recommendation for actions in Curling and Oxidation work phase

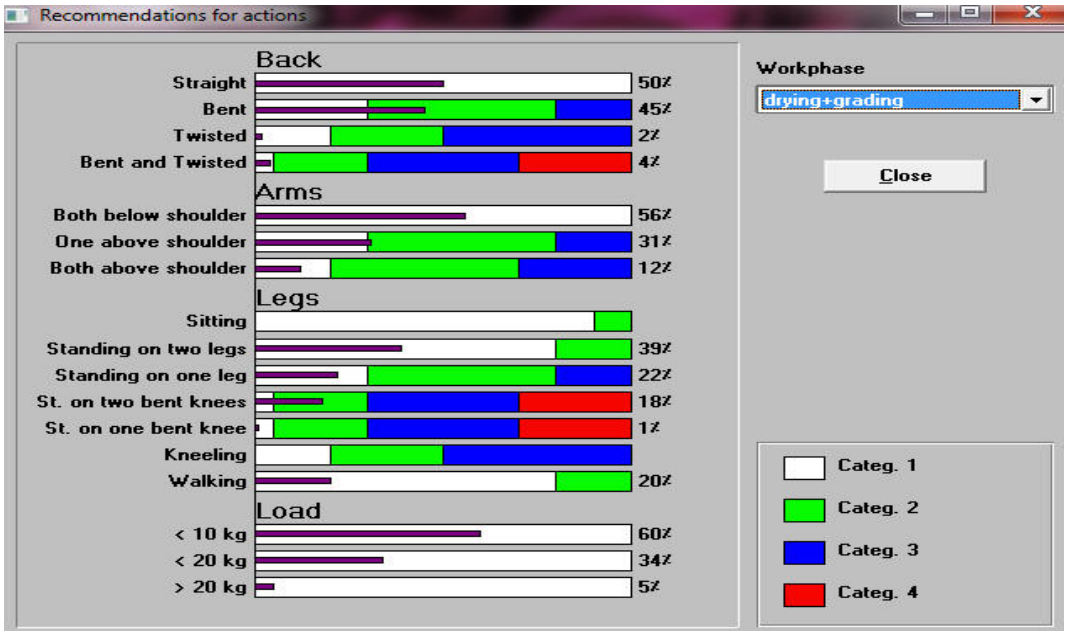

Figure 3 Recommendation for actions in Drying and Grading work phase

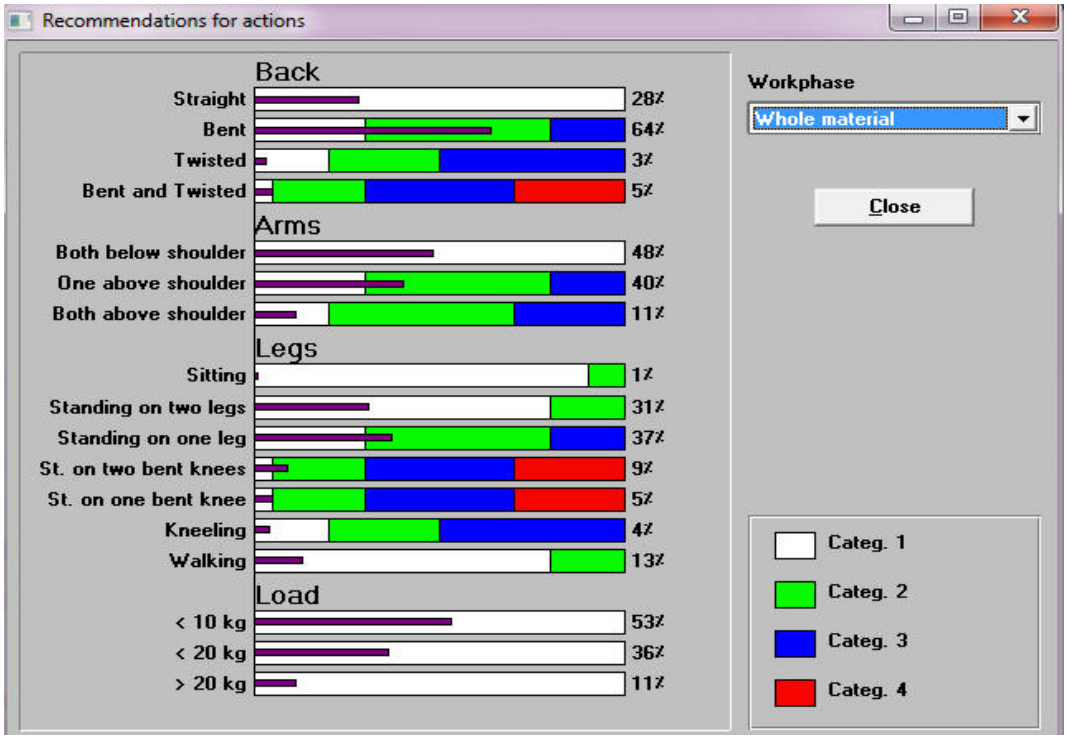

Figure 4 Recommendation for actions in whole work phase

3.3 Energy expenditure

The Energy expenditure of workers in withering unit and curling and oxidation unit was almost in the same level; but in drying and grading units, it was lower (19.730 kJ min^{-1}) (Figure 5). Work difficulty was lower in drying and grading unit, considering the nature of work. The average of energy expenditure of workers was 21.84 kJ min^{-1}. The work difficulty and high energy expenditure can be reduced with some modifications such as using conveyor, elevator etc.

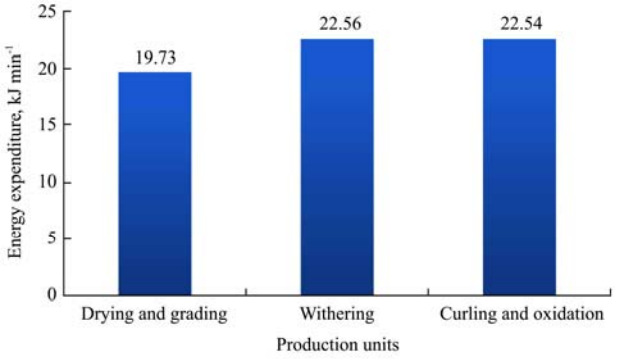

Figure 5 The average of energy expenditure of tea factories workers

4 Conclusion

Based on the REBA results, the corrective measurements are necessary for 75 percent of used postures by tea factories workers.

OWAS results showed that 34% of used postures by the workers of tea factories had high and very high risk level, so corrective measurements and workplace modification are necessary.

Based on the Winowas recommendation results, corrective measurements should be done in order to reduce workers back flexion, modifying the situations that result in placing one arm above shoulder and also situations that cause to standing on one leg. The average of energy expenditure of tea factories workers was 21.843 kJ min^{-1}.

5 Suggestions

According to the obtained results of this study, physical disorders due to bending the workers back are more than other activities. In order to control and reduce this kind of disorders, it's suggested that the height of dry tea discharging platform in the grading section should be increased. Also, the carts with standard lever can be designed in a way that eliminates the need for bending by workers in curling section. For handling the tea from one work phase to another, a conveyor can be used instead of using carts.

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